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The Fauna and Geography

of the

Maldive and Laccadive Archipelagoes

VOLUME I.

London: C. J. CLAY AND SONS,
CAMBRIDGE UNIVERSITY PRESS WAREHOUSE,
AVE MARIA LANE,
AND
H. K. LEWIS,
136, GOWER STREET, W.C.

Glasgow: 50, WELLINGTON STREET.
Leipzig: F. A. BROCKHAUS.
New York: THE MACMILLAN COMPANY.
Bombay and Calcutta: MACMILLAN AND CO., LTD.

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The Fauna and Geography
of the
Maldive and Laccadive Archipelagoes

Being the Account of the Work carried on and
of the Collections made by an Expedition
during the years 1899 and 1900

Edited by
J. STANLEY GARDINER, M.A.
Fellow of Gonville and Caius College and late Balfour Student
of the University of Cambridge.

VOLUME I.

With Plates I—XXV and Text-Illustrations 1—119

CAMBRIDGE:
at the University Press.
1903

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G222
V.1
c.2

CAMBRIDGE:
PRINTED BY J. AND C. F. CLAY,
AT THE UNIVERSITY PRESS.

PREFACE.

In March, 1899, I left England, in pursuance of my appointment as Balfour Student of the University of Cambridge, with a commission to explore and investigate the Coral Reefs of the Laccadives, Maldives, and Ceylon. As the south-west monsoon is unsuitable for work from small craft in the Indian Ocean, it was proposed to devote the summer of 1899 to a thorough survey of the atoll of Minikoi, the most southern reef of the Laccadives. In regard to subsequent work the Managers of the Balfour Studentship gave me complete latitude to do as might seem fit.

Subsequent donations of £300 from the Government Grant, administered by the Royal Society, and of £30 from the British Association, decided me to proceed in October to the Maldive Archipelago for an extended winter cruise. The latter was entirely successful in its main results, although the expedition was considerably curtailed and seriously crippled owing to the general rise in prices caused by the war in South Africa.

I would like here to express the indebtedness of my party to His Excellency Sir E. Noel Walker, K.C.M.G., late Acting-Governor of Ceylon; to the Hon. Mr Taylor, C.M.G., late Acting-Colonial Secretary; to His Highness Mohammadu Imaduddin, Sultan of the Maldives, and his Viziers; to the Board of Trade for passages to and fro between Ceylon and Minikoi; to Capt. Channer, R.N., formerly an officer of H.M.S. Challenger, now Superintendent of Lighthouses in the Ceylon district, for many valuable hints and much local information; to Sheikh Jeevunjee Noorbhai for his generous help and assistance during the time we were in the Maldives; to Rear-Admiral Sir W. Wharton,

Hydrographer, for advice and loan of scientific instruments; to Dr David Sharp for taking charge of the insect collections; to Sir John Murray, K.C.B., Prof. Judd and Prof. Agassiz for advice and assistance in many ways; and indeed to all kind friends and contributors for their aid.

Above all I wish to acknowledge the great obligations of myself and my party to Mr Adam Sedgwick for his great assistance and very active interest in the progress and work of the expedition.

In the work I was voluntarily assisted by Mr L. A. Borradaile (Selwyn College) and Mr C. Forster Cooper (Trinity College), who have largely contributed to whatever measure of success may have been attained. During five weeks in March and April, 1900, Mr Forster Cooper took charge of the work single-handed at a time when I was incapacitated by fever. My thanks are also due to Capt. Molony, S.S. Ileafaee, for his help in surveying Suvadiva and Addu atolls; and further to Mr Geo. Sheldrake, in charge of S.S. Thrunscoe, during our visit stranded on Minikoi, for practical help on many occasions.

J. STANLEY GARDINER.

August, 1901.

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INTRODUCTION.

NARRATIVE AND ROUTE OF THE EXPEDITION.

(With 2 Maps.)

At the end of March, 1899, I left England for Ceylon in the company of Mr L. A. Borradaile. On arrival at Colombo we found that the Board of Trade s.s. *Ceylon* had just left for Minikoi owing to a wreck on that atoll. This necessitated a delay of seven weeks, before we could hope to sail thither, a detention further increased to eight weeks owing to stress of weather. Mr Borradaile accordingly proceeded to the Jaffna Peninsula, where he spent a month in familiarising himself with the life and conditions on coral reefs. I meantime prepared our stores, and made arrangements for the Maldive cruise, subsequently visiting the raised limestone hills and area of the north of Ceylon[1]. After returning to Colombo I traversed the entire coast between Negombo and Dondra Head, a distance of about 120 miles. Mr Borradaile joined me, and we then settled down for a fortnight at Weligama—the Beligam of Prof. Haeckel—where there is a deep bay with reefs of small size across its entrance. The rich variety of animal life on the reefs both here and off the Jaffna coast as compared to the reefs of the Maldives and Minikoi is a most noticeable feature.

After a tedious week's detention in Colombo, we finally left Ceylon for Minikoi on June 17th, experiencing a very heavy north-west gale the whole way; in spite of this the sea one night was white with phosphorescence, a very unusual phenomenon in these waters. We located ourselves, and built a bungalow at a distance of about one-third of a mile from the south-west end of Minikoi island, under the shadow of the lighthouse, the boat belonging to which was through the kindness of Capt. Channer, R.N., freely placed at our disposal. The island here is about 470 yards across between tide-marks, and a broad ride has been cut, giving the only open space of any size in the island. The vegetation is extremely dense, and forms a low jungle of *Pandanus*, *Hibiscus*, *Hernandea*, *Ricinus*, coconut and other trees, with *Pemphis acidula*, *Scaevola koenigii* and *Tournefortea argentea* on the shores. At the south-west end of the island is a shrine, the grave of a holy, Moslem sheikh, connected by a good, shaded path with the village in the centre of

[1] Vide *Report Brit. Ass.*, pp. 400—2, 1900.

the island. A small settlement formerly existed round the shrine, but it has long been abandoned, and the jungle near it is now far thicker and less trodden than elsewhere. The land has the same character up to the village, but further north it is much more open, and can indeed be traversed almost anywhere[1]. Our situation then was not unnaturally the best possible for the land fauna, on which the lighthouse lamp too had doubtless no inconsiderable influence. The open ride formed both by night and day our best collecting ground, sugaring never meeting with any measure of success elsewhere.

For marine observations and collecting, we had within a stone's throw of the house on the seaward face of the island a broad reef-flat, on which the sea continually breaks. Towards the north this gradually narrows, but westwards broadens, and continues round the atoll. A broad boulder zone, which can be waded conveniently up to half-tide, extends the main (Minikoi) island inside the reef-flat to Wiringili and thence to Ragandi and round the atoll. These islets are mere rocky patches, the former with a few coconut trees, under the shade of which strangers are buried. Towards the lagoon there is a great sand-flat, exposed at spring tides from 100 to 200 yards from the beach. The situation was also chosen, as during the summer months the south-west monsoon blows, the effect of which I wished particularly to study. Unfortunately the monsoon of 1899 was very abnormal, the prevailing winds coming from west to west-north-west until the second week in August, when the proper monsoon commenced, bringing heavy rain in its train. The latter made work extremely difficult and unpleasant; the bottom could nowhere be seen on account of the surface disturbance; bottom living animals contracted, or retired into the sand or other shelters; the surface fauna sank to considerable depths.

The disadvantages of the position lay in the considerable distance of the house from the village and from the north passage into the lagoon, through which alone access to the open sea could be obtained in this monsoon. Natives had to be hired from the village for each several job, and it was too far for the children or fishermen to bring any strange animals they might find. The wind being dead in our teeth, and the numerous shoals making short tacks necessary, it was difficult to visit the northerly reefs of the atoll, and on no occasion was I enabled to approach them from seaward within about 200 yards.

During the months of July and August a heavy easterly swell came up with large rollers, three times dying down and again regaining force. This swell was very abnormal at the time of year, and apparently was due to some cause completely outside the ordinary winds and currents. On enquiry I ascertained that it was also observed on the east coasts of Ceylon and India and on the large Ocean Liners proceeding from Ceylon to Albany. Subsequently I found that it had been felt throughout the whole of the Maldives; in Suvadiva and Addu it did considerable damage, sweeping over islets and land, which had never been

[1] Owing to an old arrangement the produce of half the island is deemed to belong to the Bebe of Cannanore. An arbitrary line of division exists near the village with gates and guards, who rigorously exact three-fifths of the coconuts gathered south of the fence. In this portion no timber of large size or old growth exists, the whole surface at one time having been cleared and planted. Subsequently on the hold of the Bebe becoming weakened or relaxed, vegetation was allowed again to assume its sway, resulting in the present dense, jungly growth. On the management of the Bebe's dominions being undertaken by the British Government, the old line of division as found was retained permanently with much injustice to the inhabitants, as it had been formerly periodically open to revision. Since that time the north half of the island has been very rapidly washing away, while the south half has, if anything, been increasing somewhat in breadth. The north half cannot now annually support one-third of the present population, while the south has become a dense jungle, rapidly going to waste. It produces annually under the present system only a few hundred rupees' worth of coconuts, which the government might well commute for a fixed annual charge.

affected before. The origin of the swell can only, I consider, have been due to submarine volcanic disturbances probably towards the East-Indian region.

During the first five weeks of our stay at Minikoi, while I was engaged in a survey of the land and shores, Mr Borradaile occupied himself mainly with a thorough study of the land Crustacea[1]. An incautious exposure on the reef, while collecting, then laid him up with sunstroke, so that I had no option but to send him to Ceylon, whence he was ordered to return as soon as possible to England. For the remaining eight weeks I was absolutely alone, being deprived by illness even of my Singhalese servants.

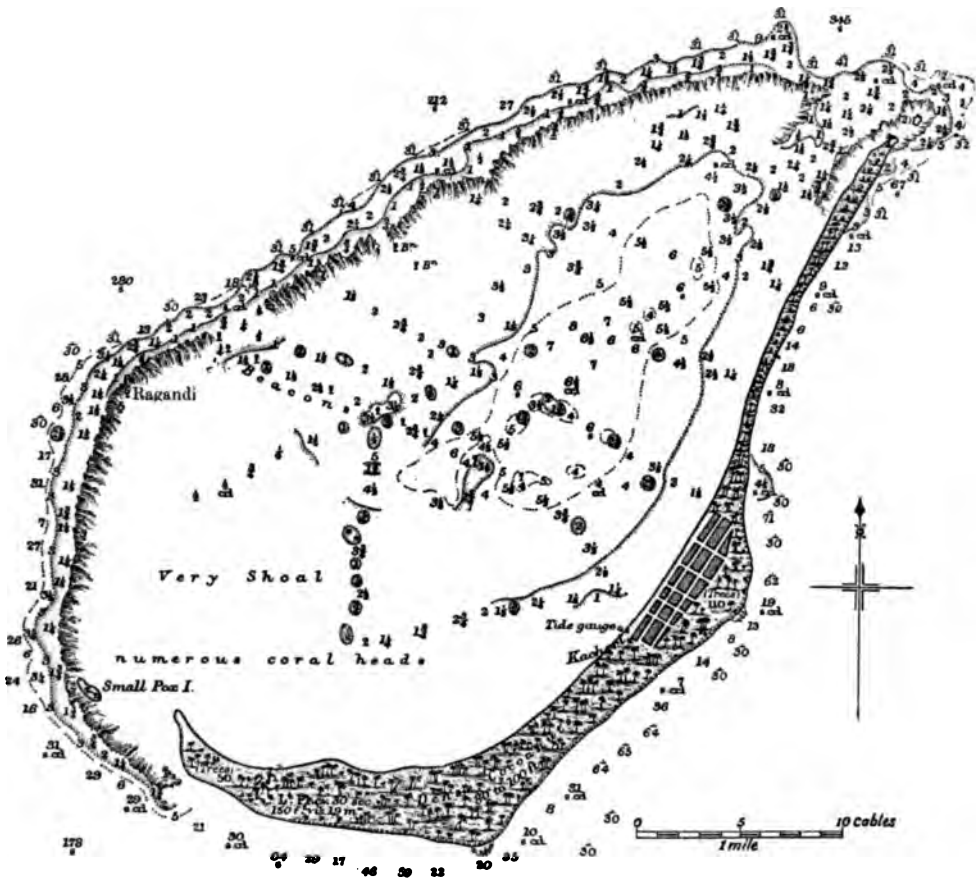

FIG. 1. Minikoi Atoll, from the Admiralty Chart. (*Wiringili, native name for Small Pox I.*).

I returned to Ceylon in the middle of September, Mr Forster Cooper shortly afterwards joining me from England. After some unavoidable delay we left Colombo on Oct. 18th for Male, the capital of the Maldives and residence of the Sultan. Owing to a succession of accidents we did not arrive until Oct. 23rd, when we at once landed our stores, transferring sufficient for a three months' cruise to our schooner. The latter was lent to us by His Highness the Sultan; she was a vessel of about 16 tons, built in the islands, of coconut

[1] *Vide* Mr Borradaile's account in the same part of this publication.

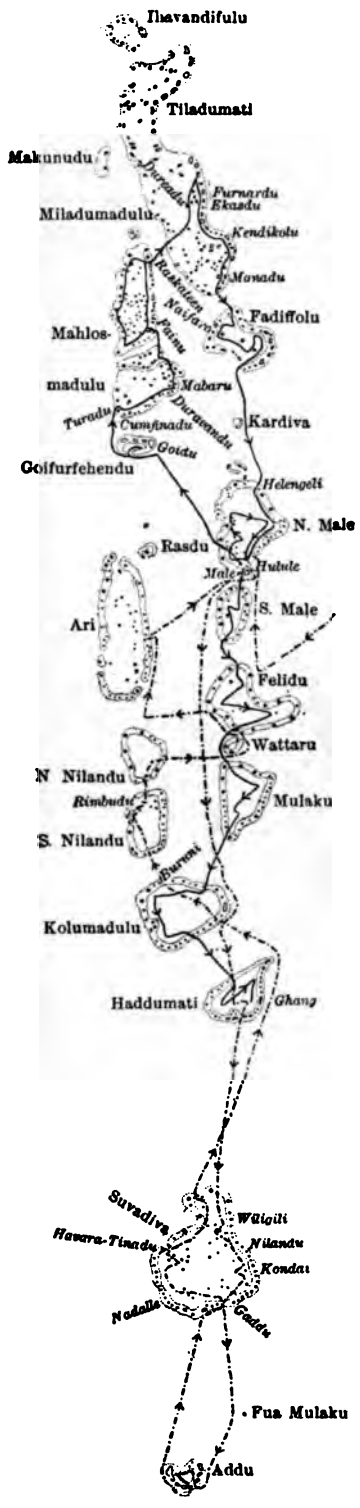

FIG. 2. Maldive Group, showing the route of the expedition. *Scale 60 miles to 1 inch.*

wood, moderately seaworthy, but not laying within six points of the wind. The Sultan also appointed Hassan Didi Velana-manikofanu, his third vizier, to accompany us, and gave orders that every facility should be granted to us. After presenting our offerings to the Sultan and his viziers, we sailed from Male for Goifurfehendu (Horsburgh) atoll.

We at once had a house built on Goidu island, from which as centre we visited all the other land of the atoll and the greater part of the reef. A stay of altogether eleven days was made, and everything was unpacked and properly stowed on the schooner; the dredges and instruments were overhauled, and indeed all preparations were completed for the work in Mahlos and other atolls. The reef-animals were collected and preserved, being sent by native boat to Male to await our arrival. On leaving Minikoi I brought with me two boys, whom I had taught to collect in that atoll; these I largely employed in Goidu and subsequently in other islands in collecting the land fauna and flora.

The remainder of October, 1899, was spent in S. Mahlos-madulu. This group of reefs really consists of three atolls, a small central one separated from larger on each side by narrow channels of over 100 fathoms in depth. The three lie on a shallow bank, which tapers to the north but has a broad base to the south-east. The plateau is studded all over with reefs, the outside ones forming a chain round the perimeters of the three parts. The reefs along the west side of the bank are for the most part ring-shaped, small atolls (atollons or *faro*) with deeper water (the lagoon or *velu*) in the centre. On the east and south sides, however, isolated islands with fringing reefs mostly form the boundaries. The general depth of the atolls is about 27 fathoms, most of the channels between the numerous encircling reefs having over 20 fathoms.

The weather during our stay in S. Mahlos was extremely calm, our vessel indeed being towed by boats from island to island. This was singularly unfortunate, as usually strong winds may be depended upon in November. We had hoped to syste-matically dredge a large number of the deep channels between the reefs, that edge the atoll. As their general depth is about 25 fathoms, this was found to be impracticable, rowing boats not having sufficient weight to carry even the smallest dredges along a rough bottom at this depth. Accordingly we confined ourselves to a traverse of the whole south of the atoll. Our first anchorage was off Turadu, an island situated on the rim of a somewhat ill-defined *faro* at the south-west corner of the bank. We visited every part of its reef and collected a few animals. The lagoon (*velu*) of the *faro* was dredged, yielding

Asymmetron and *Ptychodera* from 20 fathoms. The island itself proved most interesting. Its rocky barrier of beach-sandstone had in 1896 been overlapped by the waves of a cyclone. These attacked the sand behind, eating deeply into the island, with the result that the beach-rock has been left in lines many yards from the shore. The natives have now erected breakwaters round a great part of the island—and also a new mosque—but in spite of these no trace of it is likely to be left in 20 or 30 years' time, unless some considerable change in the currents or reefs alters its conditions.

From Turadu we visited all the reefs to Mabaru, the most easterly point of the whole group, anchoring at Hitadu, Heddufuri, Mahrus and Duravandu. At Cumfinadu we found some large rocks, standing up in the lagoon well inside the boulder zone; *Bonellia* was living on the reef-flat, and *Ptychodera* was the most abundant form of life on the shores of the island.

We finally left for N. Mahlos on Nov. 29th, but, meeting with strong currents to the west-south-west, we only fetched Kuderah-Heelu in the central atoll that evening. However we reached Fainu in N. Mahlos on the following day, and remained there at anchor for three days, which were devoted to dredging and an examination of the islands of Fainu, Kenurus and Ingurahdu, and Berriam-furi faro. We then separated, Mr Forster Cooper dredging with the schooner along the east side, and examining its islands and reefs. I meantime embarked in a small open boat for the western side, where the lagoon of the atoll is filled up with a perfect maze of small reefs and shoals. I first visited five of the lagoon islands, and then, a strong north-east breeze setting in, worked up along the edge of the atoll, sailing from dawn to dusk, and anchoring at night to leeward of the nearest reef. I examined all the reefs and islands, and sounded the velu (lagoons) of all the faro (atollons) along the western rim, rejoining the schooner on Dec. 11 at the north of the atoll. Unhappily a series of collections, made by myself and my boys, to illustrate the populating of sand-banks by both animals and plants, was ruined by my capsizing our fishing boat near Cunderudu.

On Dec. 12th, after taking in wood and water, we sailed for Miladumadulu, a similar bank to Mahlosmadulu but with relatively far fewer reefs and a less determinate rim. We anchored the same night at Guthardu, and at daybreak made sail towards the east side of the atoll. Owing to a strong south-westerly set of the current we took two days in reaching Dureadu in the middle of the bank, a distance of seven miles. This is the island of a round faro, one mile in diameter; its lagoon has 19 fathoms of water, a depth which makes the faro peculiar among all its fellows in the Maldives. We landed the same night for firewood and water, but, none of the latter being obtainable, were compelled to sail at dawn. A strong north-east gale coming out, we stood up the atoll and watered at Rymaggu, anchoring that night at Furnardu, a large island on the east edge of the atoll. The islands of this rim of Miladumadulu tend to be closely fringed by the reef on all sides, and to have a *kuli* (shallow lake, French *barachois*) in the centre, surrounded by mangroves, through which the sea has in some found access. While Mr Forster Cooper dredged with the schooner down to Kendikolu, I visited ten of these islands in a fishing boat; two were very small, three had definite kuli or else mangrove swamps (Ekasdu, a large lake swarming with a species of *Leander*), and four were crescentic in shape, their kuli now open to the sea. Kendikolu is one of the largest islands in the Maldives, being two-and-a-half miles long by two-thirds of a mile in breadth. There are four kuli down the centre surrounded by mangroves, which abound in rails; on their surfaces we saw

a few duck, while their waters, which are quite fresh, four to five feet deep, teem with small fish. However, as Ramazan, the Mahommedan fast month, was approaching, we had to hurry on, and only stayed two nights. We accordingly, on Dec. 19th, dredged down to Landu, obtaining a large variety of sponges and Polyzoa with a quantity of red *Polytrema* and some nullipores, in addition to corals, of which the black *Dendrophyllia ramea* was very abundant in 12 to 20 fathoms off the reefs. We visited and dredged Ma and Eddu faro with three to four fathoms of water in their velu, obtaining a few Cephalochorda, and examined some of the central islands of the atoll. At Manadu we caught a single specimen of *Typhlops*, which is evidently very rare in the archipelago, since it has no native name.

Fadiffolu atoll was reached on Dec. 23rd; it differs from the preceding in being a true atoll, having a well-defined, encircling reef, especially to the east, and an open lagoon with but few shoals. We first moved down the east side, examining the reefs, but then dredged across to Innawari. The natives, although not actively hostile, were very unfriendly, so that on Christmas morning we sailed down to Naifaro. The winter rains now commenced, and continued intermittently with heavy squalls from the north-east for a month, making navigation among reefs difficult. The schooner too was decidedly unpleasant, as the whole of our cabin accommodation had to be utilised for storing our books, instruments and various collections. We remained at Naifaro four days, restowing and repairing our vessel, as she had been somewhat strained in the recent heavy weather. The time was occupied in a survey of the neighbouring islands and reefs, and in thoroughly dredging some of the passages into the atoll.

The shores of all the islands at the north end of Fadiffolu I found abundantly strewn with the shells of *Spirula*. Enquiring of the natives as to its "fish," I was surprised to receive an accurate description of it. It appeared that the animals were extremely abundant in January of 1897 in the channel towards Miladumadulu. "They float on the surface, and may be picked up with the boat-bailer. They are never seen inside the atoll, but periodically occur in the north-east monsoon in the open sea. None were seen in 1898." I offered a reward of 50 rupees for the first specimen, but, although eight or nine boats went out daily during my stay, I did not secure one. That the people of Naifaro and Innawari really know the animal is undoubted. Yet this is peculiar, as I did not find on close enquiry that it was known to the natives of any other part of the whole archipelago, though its shell occurs sparingly everywhere. The native name for the shell is *markana taludandi*, the heron's key.

Leaving Naifaro we again dredged across the atoll on a more southerly course, subsequently cruising along the eastern side, dredging and examining the islands and reefs. On Jan. 2nd, 1900, we set sail for Male atoll, anchoring off Helengeli the same afternoon. This atoll is intermediate in its characters between Mahlos and Fadiffolu; except at the south end it has practically no islands in the lagoon. There are evidently great changes in its topography since the original survey, two islands of the eastern edge at least, resting on their own reefs, having disappeared. There seemed to be still greater alterations in respect to the shoals in the lagoon, but in our somewhat dependent position any real survey was impossible owing to constant interference from Male. We, however, saw some of the western reefs on our way to Goifurfehendu, and on our return journey to Male, which we reached on Jan. 5th, 1900, we dredged down as close as possible to the eastern reefs. Further Mr Forster Cooper in the middle of February made a most successful

dredging cruise of eight days in the atoll, taking 34 hauls, to ascertain the character of the bottom in every position, and I at the same time visited most of the islands and reefs within five miles of Male.

Ramazan had now commenced, and, dependent as we were entirely on Mahommedan boys, it would have been useless to continue our cruise. Our vessel too was in want of a thorough overhaul, the rigging being very bad. After a couple of days in Male, we had a house erected on Hulule, the island of a neighbouring faro, and at once transferred to it sufficient stores for a stay of four or five weeks' duration.

Hulule island is about 1¼ miles long by 800 yards broad; it is about two miles distant from Male. The greater part of its surface is covered with coconut trees, but a large patch along the western side has been allowed to revert to jungle. The principal trees are the banyan, candle-nut and *Calophyllum*, the branches of which abound in frugivorous bats. On account of the island's proximity to Male, where all foreign vessels for the group have to enter, many plants have been introduced. Few of the fruits thrive, but half-a-dozen brilliant flowers relieve the everlasting green. Sweet-smelling plants, jessamine, frangipanni, roses and various herbs, make the proximity of the mosque and village pleasantly fragrant. The western shores are fringed with *Pemphis acidula*, the white, perfumed flowers of which prove a great attraction to insects. As some of our boys delighted in this work, the land fauna and flora was exhaustively collected. As compared with Minikoi, we found the insect and spider faunas to be decidedly poor except in butterflies, although it may be deemed to be thoroughly representative of any rich island in the centre of the Maldives. A certain number of insects must have been introduced with the plants, but the successful acclimatisation of any considerable number of the latter only dates back to the eruption of Krakatoa in 1883. Before this time pumice (*feng-bo-ga*, the water-swimming stone) was not known in the group. Its fertilising properties have now been discovered, and in many islands baskets of it are collected and strewn over the garden land. The capture of two specimens of snakes on pandanus trees at Hulule was of interest.

The whole faro is 4½ miles long by 1½ broad; its lagoonlet, or velu, in the centre has a depth of 6 to 7 fathoms. The reef everywhere is awash at low tide, and, though differing greatly in its characters, quite well defined on the side towards the lagoon of the large atoll. Besides numerous rocks there are two islands respectively at the north and south ends, Farukolufuri and Hulule. During our stay every part of the faro was surveyed, and the fauna carefully collected for comparison with that of Minikoi atoll. *Asymmetron* was very abundant in certain places in and around the velu, and at least three species of Enteropneusts of two or three genera were found, each in its own characteristic environment. Two specimens of a remarkable *Thalassema*, 2 feet long when alive, were secured from the boulder zone, besides a number of specimens of smaller species. The sand was remarkably rich in Actinians of many species, all of which withdrew into the shelter of the sand at every rain-squall. Mollusca were not numerous, but *Cryptoplax*, *Chiton*, and each of the three families of the Zygobranchiata were represented; autotomy of the foot seems to be a widespread phenomenon, as several forms with the foot thus cut off were obtained.

We returned to Male in the middle of February. Mr Forster Cooper at once sailed for his dredging cruise in the atoll, while I remained to carry on a series of observations

on the currents in the channels on each side of the island. During my whole stay I dispensed medical aid freely to the people. At this time there was in one district of Male an epidemic of malaria, with which I was naturally much brought into contact. Mr Forster Cooper returned to find that I had caught the infection. I saw, however, our collections to date properly packed for England, and the schooner victualled and equipped. As complications set in and I was getting worse instead of better, Mr Forster Cooper on Feb. 28th took advantage of the chance visit of a British India Steamship Co.'s steamer to place me in charge of Capt. Pigott, R.N.R.[1], for Colombo. He himself determined to carry out his part of the projected work, and sailed from Male on March 3rd for the southern atolls.

I cannot speak too highly of the pluck, determination and resource, shown by Mr Forster Cooper, who had had no previous experience of the tropics. He worked his native crew in a manner, which I have never seen excelled even in the Pacific, and took no less than 88 dredgings in five different atolls. However, I append Mr Forster Cooper's report, which may be allowed to speak for itself:

"On March 3rd, accompanied by Mahommed Didi as interpreter and representative of the Sultan, I crossed over to S. Male, in which three days were spent. Gurahdu island and reef were visited, but neither land nor reef in the atoll appeared to exhibit any novel features. The group consisting of a series of almost isolated reefs, I dredged principally in the outer passages and in the centre to ascertain the differences in the bottom-fauna. The hauls in the centre were very unproductive, but in the channels a large quantity of the same sessile forms, as in the northern atolls, was brought up. Just inside the northern passage a coral, *Goniopora stokesi*, was obtained; it forms round heads on thick stalks, covered by an epitheca, which is completely buried in the sand, or mud.

"On March 6th we sailed on to Felidu atoll, where we visited Alimata and Tinadu islands alone, at night anchoring generally to the nearest reef. We remained eight days, but only took 18 hauls of the dredges owing to head winds, strong currents across the atoll and dead calms. Indeed throughout the whole cruise the unfavourable winds and the poor sailing qualities of the schooner prevented us from surveying as much of the atolls and from taking as many dredgings, as I would have liked. We attempted for three successive days to get up the almost completely enclosed eastern horn of the atoll, but were unable to tack up more than half-way. The lagoon in it is open with few reefs or shoals, and has a general depth of 40 fathoms; its bottom is hard, covered with sand, and absolutely unproductive to the dredge. In the rest of the atoll weed and broken shells were found towards the centre of the lagoon and rubble in the channels. *Diaseris* is very common almost everywhere and its skeleton forms one of the chief constituents of the rubble.

"We fetched Mulaku atoll on March 14th, and remained six days, taking 17 dredgings. The atoll is remarkable for the broad, almost continuous reef along its eastern side. There are a number of very narrow, shallow passages to the north, but from Maduveri to Curaille a distance of 30 miles, the reef is continuous save for a single passage opposite Mulaku island. All the islands lie on the seaward side of this reef; extending down its centre is a series of long, linear velu (small lagoons), which off Raimandu is double, two series lying parallel to one another and the edges of the reef. In dredging I ran two lines across the lagoon, and then moved down along the eastern side. Among other forms we collected a

[1] I cannot sufficiently express my indebtedness to this gentleman for all his kindness to me.

large number of soft-bodied echinoids, a few black crinoids and some holothurians, with which were associated a number of Polychaeta, crabs, caribs and molluscs. All were of the same ground shades as their various Echinodermata, whose colour was, as it were, photographed upon them.

"Kolumadulu atoll was entered on March 21st, but no work could be done from the schooner owing to the calm weather until the 26th inst. I meantime took the small boat out, and made various scattered dredgings in the north-east corner of the atoll with but indifferent success, while I sent the collecting boys to Kolufuri to obtain the land fauna and flora. I did not personally visit any of the islands in this atoll nor Haddumati, which we next dredged, as they all appeared to me to present the same features as in the northern groups. I was also anxious, as these two atolls are almost completely encircled by reefs, to ascertain precisely the characters of the bottom in every part. I sailed finally right across the centre of Kolumadulu lagoon, taking 16 dredgings down to 45 fathoms and incidentally running the vessel ashore on a small reef, off which we warped her without any great difficulty. The centre was found to be covered with fine mud, on which a few Crustacea, molluscs and flat-fish of small size alone appeared to exist. We obtained also a larval form of *Fierasfer* out of a holothurian from 25 fathoms.

"In Haddumati atoll I took 16 dredgings in the centre and eastern part of the lagoon, where the bottom was mostly covered with fine mud. They were very unproductive owing doubtless to the all but continuous reef of the eastern side. Relatively little work could be accomplished, as the schooner was in a horribly dirty state with bilge, etc.; she also had been somewhat strained on the reef, and her bottom was thickly covered with barnacles and weed.

"To summarise, the cruise yielded between March 3rd and April 8th 88 dredgings in every part of the lagoons of five different atolls. The hauls must have averaged at least one mile each, and hence 88 miles of the bottom was covered. The latter was found to be of an almost uniform dead-level between the reefs and shoals, which, arising precipitously, uniformly reach to within a few feet of the surface. It was to me most remarkable that we did not meet with a single knoll of any sort jutting up to indeterminate depths[1]."

After paying a second visit to the Jaffna district, I returned to the Maldives, having secured Sheikh Jeevunjee Noorbhai's steamer Ileafaee, Capt. Molony, for a short cruise. I took on board at Male Mohammed Didi, Chief Vizier and uncle to the Sultan, Mafekiligefanu, the religious head of the community, and Hassan Didi, third vizier, with their suites as well as a Said, descendant of the Prophet, who had a family in Addu. After discharging some of our Male cargo we steamed south down the deep central basin of the group, coasting S. Male and Kolumadulu atolls. We steamed into Haddumati atoll on April 8th, and relieved Mr Forster Cooper, who joined us. After transferring the collections, instruments and nets, we sent the schooner back under the native mate to Male, and at once sailed on to Suvadiva atoll, which we entered by the north-east passage on the morning of the 9th. This atoll lies between the equator and lat. 1° N.; it is separated from the central group by the "One and a half Degree Channel," 55 miles in breadth.

[1] It is scarcely necessary to point to the great importance of this fact, as bearing on the question of the formation of the atolls and reefs of the Maldives.

It has a well-defined rim with passages at intervals, and is about 34 miles long by a little less in breadth; its lagoon has a maximum depth of 50 fathoms. As Addu atoll was to be our turning point, we now spent only two days in Suvadiva, dredging and sounding along the east side of the lagoon. We anchored with banked fires for two nights at Nilandu and Gaddu, and I further, leaving the dredging to my companion, visited Wiligili and Kondai.

Addu is a small atoll, 10 miles long by 6 broad, lying about lat. 0° 40′ S. Its reef is perfect except for two small passages to the north and two larger ones to the south. The lagoon has a maximum depth of 36 fathoms; it is fairly open in the centre, but against the encircling reefs has a perfect maze of coral heads, arising from 7 to 10 fathoms. It is noticeable that the greater part of the circumference of the atoll is surrounded by land. The "Equatorial Channel," 48 miles across, separates Addu and Suvadiva. In its centre is the island of Fua Mulaku, said to have a deep kuli (lake) in its midst; it is two miles long by one broad, and has a fringing reef only. On our passage to Addu, and subsequently on our return journey, we tried to visit it, but the heavy sea made both anchoring and landing quite impossible. We remained at Addu until April 15, examining the reefs and islands, in both of which there have been great changes since Moresby's survey. We also checked the soundings on the chart, and took 14 hauls of the dredge in the lagoon and on the outer slopes. In one of the latter from 40 fathoms we obtained a large quantity of *Heliopora coerulea* with almost colourless corallum. The vegetation of the islands was far more luxuriant than any we saw in other parts of the Maldives, but the land fauna was very scanty as compared with Hulule. The animal life of the encircling reefs seemed to be both poorer and less varied than to the north; the growth of fixed forms of life in the lagoon was, however, decidedly lavish.

Revisiting Suvadiva on our return journey, we dredged and sounded within the lagoon along the south and west sides, anchoring for three nights at Gaddu, Nadalle and Havara-Tinadu, beyond which I did not land anywhere. On April 19th we entered Kolumadulu, having in the morning coasted along the east side of Haddumati. We dredged the passage, as we entered, and dropped anchor at Buruni, at once going on shore.

On April 20 we ran a line of soundings across to S. Nilandu, an atoll somewhat similar to Male. We twice traversed the lagoon, anchoring that night at Rimbudu. Six dredgings were taken in 19 to 35 fathoms; they proved to be in their result the richest series that were obtained in the whole archipelago, although I do not think we found any forms of which we had not previously preserved specimens.

On April 21 we sounded the channel across to N. Nilandu atoll, which we crossed. We then ran a line of soundings to Wattaru atoll across the central basin, which has very generally been supposed to owe its origin to the lagoon of a much larger atoll, now completely lost. We further sounded the channel between Mulaku and Wattaru atolls, anchoring for the night off Rakidu in Felidu atoll. On April 22nd we sounded the channel between Felidu and Wattaru atolls, and then ran a second line across to the western chain, about 15 miles north of the first. We sounded the channel between N. Nilandu and Ari atolls, continuing northwards sounding at intervals to Mahiaddu in the latter atoll, where we dropped anchor. On April 23rd we made a straight course for Male, putting down our third line of soundings across the central basin. We ran our line out

along the channel between N. and S. Male atolls, obtaining finally a depth of 1005 fathoms, two miles S.W. ¼ W. of the S. point of the reef of Hulule faro. That night we anchored off Male and, after taking our collections on board, bade good-bye to the Maldives on April 25, 1900.

The collections may be allowed to speak for themselves in the subsequent parts of this publication. A word is necessary as to the dredgings, of which 273 were recorded in the Maldives. They were intended to ascertain the character of the bottom within the atolls as well as its fauna in every position, in which the physical conditions might vary. Naturally a considerable number were under these circumstances absolutely barren, but all served their purpose. Seven dredges were used, both rectangular and triangular, of Naples or Plymouth models, as well as an otter and three beam trawls of 3, 4½ and 6 feet. The latter were made to my own design, an adaptation of Prof. Agassiz' model; they were for trawling from the steamer weighted with fire-bars; their nets were of coconut fibre (sinnet or coir), and were made by my boys. Swabs of hempen rope, three feet long, were found best adapted to our work; they were always thrown overboard, when we were at anchor, about one fathom of rope being allowed beyond the depth, if the bottom was fairly level. For sounding from the schooner and small boats, besides regular lead lines, we used loosely spun cod-fishing line, as recommended by Mr J. Y. Buchanan. On the steamer we had an old Lucas deep-sea machine, which was lent us by the Admiralty, Mr Lucas kindly providing about 3000 fathoms of wire. Of leads we employed the Telegraphic Construction and Maintenance Company's snapper, and valved leads of the Admiralty pattern. Other apparatus and instruments will be referred to where necessary in the account of the work of the expedition.

J. STANLEY GARDINER[1].

[Note. The collections of plants have been presented to the Royal Botanical Gardens, Peredeniya, Ceylon. A full report on them will be shortly published in the "Journal of the Gardens" by Mr J. C. Willis, the Director. J. S. G.]

[1] This account has been checked by Mr L. A. Borradaile and Mr Forster Cooper.

THE MALDIVE AND LACCADIVE GROUPS WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN.

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(With Plates I. and II. and Figs. 3—11.)

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(*To be continued.*)

CHAPTER I.

THE CORAL REEFS OF THE INDIAN OCEAN.

THE topography of the Indian Ocean gives but little aid to the student in attempting to determine the character of the foundations of the various island groups. Far less indeed is this the case here than in the Pacific Ocean, where the trend of each of the larger groups has a tendency to run somewhat parallel to that of others and to continental land, suggesting that they lie on lines of weakness of the earth's crust, lines of former volcanic activity. The two oceans are alike in that the western part of each is almost bare of coral islands, the Pacific absolutely so, the Indian Ocean with Cocos-Keeling[1] and Christmas islands[2] alone. Of these the former is the type, on which descriptions of most atolls have been moulded, and the latter is an ancient atoll, which has undergone great elevation, the only one indeed in the whole Indian Ocean. This lack of raised reefs is remarkable, as compared with the Pacific Ocean, and can only be taken as an indication of the absence of any considerable volcanic activity in modern times, at any rate between Madagascar and India.

There are only two changes in the past in connection with the topography of the Indian Ocean, about which there is any general consensus of opinion, *i.e.* a former water connection with the Atlantic Ocean, and a land connection between Madagascar and Africa. The permanency since the Jurassic period of the Arabian Sea and of the great basin between Chagos and Rodriguez on the one hand and Australia on the other has not been seriously impeached, so that there is only left a belt between S. Africa and S. India, and it is in this that all the considerable coral reefs lie. The general depth of the whole Indian Ocean is remarkably uniform, about 2500 *f.* (fathoms), a single sounding only of over 3000 *f.* (3097 to the S.W. of Christmas island) having been obtained. What however is still more noticeable is, that not a single sounding N. of the line between Cape St Mary (S. Madagascar) and Cape Leeuwin (S.W. Australia) has been run of less than 2000 *f.* except near continental land, or close to islands and shallow reefs, the existence of which is known at the present day. The soundings, such as they are, although not quite close enough, give strong indications, that the belt between Madagascar and India is cut by a depth of over 2000 *f.* in three places, *i.e.* between the Maldives and Chagos, between the latter and Saya de

[1] *Vide* "*The Structure and Distribution of Coral Reefs*," by Chas. Darwin (1889) and "The Cocos-Keeling Islands" by H. P. Guppy, *Scottish Geo. Mag.* (1889).

[2] *Vide* "A Monograph of Christmas Island, Indian Ocean." British Museum (1900).

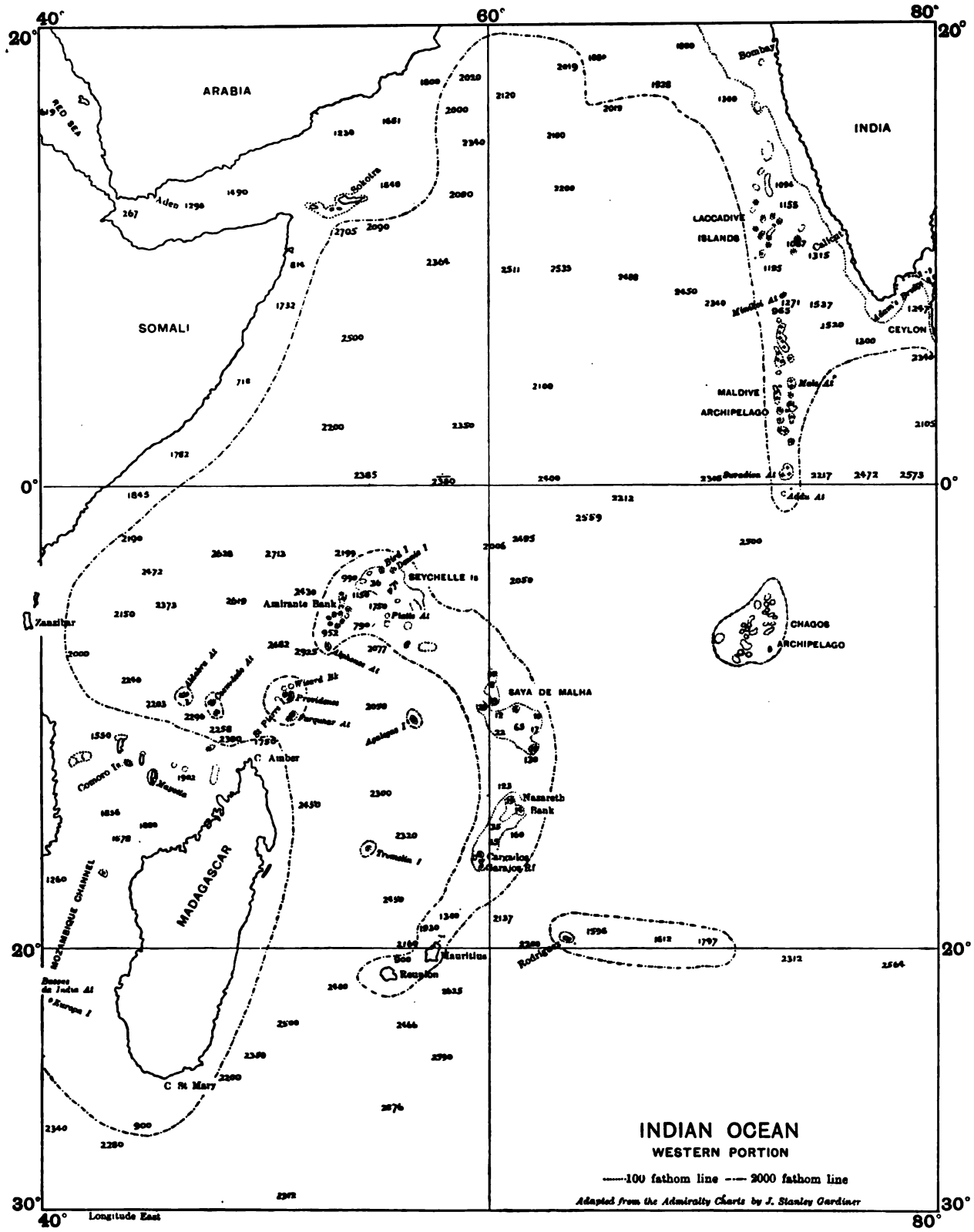

FIG. 3. Indian Ocean, Western portion.

Malha Bank, and between Farquhar atoll and Madagascar. These channels divide the coral-reef areas into four sections, which may be termed respectively the Malagasy, Seychelles, Chagos, and Maldive[1].

1. MALAGASY SECTION.

Madagascar itself displays a nucleus of granite running from end to end of the island, broken only by patches of recently active volcanoes. No raised rock of coralline origin is known, but nummulitic limestones of the eocene period form a belt along the western side. The reefs round the island are of inconsiderable extent, mostly mere isolated fringing banks. The former connection of this island with Africa is indubitable, and its structure indicates that it has experienced several changes of level since that connection was broken down. The Comoro islands, a volcanic group N.W. of Madagascar, have only fringing reefs except Mayotta, which possesses a barrier, 3 to 6 miles distant, with upwards of 35 *f.* of water in its lagoon. Two small high volcanic islands arise in the barrier itself, indicating that its formation was probably *sui generis*, on a bank formed of volcanic debris from the central island.

Of isolated coral formations there are to the south about lat. 22° in the centre of the Mozambique channel Europa island, 50 to 80 feet high, with low cliffs and sandy hommocks, and a small fringing reef, and the Bassas da India bank, a round atoll-reef 9 miles in diameter, completely enclosing a central lagoon of shallow depth. Between the Comoro and Cape Amber (N. Madagascar) are a series of banks, of which the Geyser is to all intents an atoll with a wide passage to the S.E.; Glorioso has two islands, for which the descriptions do not indicate any elevation.

To the north of Madagascar, about lat. 9° 50′, are a series of banks and islands, which show an unmistakeable and very uniform elevation of something over 30 feet. Of these two banks to the east Providence and Wizard never probably had an atoll form, they have now merely sand cays (Providence two small islands as well) and isolated rocks, while St Pierre in their vicinity is a raised island, one mile in diameter; its elevation would seem to have been but very recent, as it is described as having no fringing reef, the sea directly breaking on its coast. In addition there are three indubitably raised atolls, Cosmoledo, Farquhar and Aldabra. They differ from most similarly elevated atolls, in that their rock still retains even at the surface its organic structure. The lagoons of the original atolls can in each be traced, and the greater part of their basins appears to be covered with water at high tide, although their mud-banks increase in extent in the order named. It is remarkable that the lagoons of all have maintained, or obtained passages with a few fathoms of water to the sea, and they would appear to be regaining their former extent. Aldabra, 19 miles long by 7 broad, has save for two small passages a perfect rim of land, covered by jagged coral, while its lagoon is surrounded by mangroves, which are said to be everywhere "eating the coral away[2]."

[1] The southern islands of the Indian Ocean (Prince Edward, Crozet, Heard, Kerguelen, Amsterdam and St Paul) are separated by at least 1200 miles of ocean from the nearest islands of coral formation, or with coral reefs of any sort. They are all volcanic, and can have no conceivable connection with the islands to the north, being separated from them by over 2000 *f.* They must be regarded rather as outliers of the great Antarctic Continent, since they all rest on the somewhat shallower bank, which extends northwards from its shores.

[2] "Islands in the Southern Indian Ocean." *Admiralty*, p. 366, 1891, from which also much of the information in

2. SEYCHELLE SECTION.

This section comprises a semicircle of reefs and islands, extending from Reunion to the Seychelles and then southwards to the Amirantes and the Alphonse-Francois islands. Rodriguez is an outlying basaltic island to the east of Mauritius, with a little raised coral-rock; the reef is fringing or slightly barrier with low coral islets[1]. Agalegas and Tromelin between the line and Madagascar seem to be of coral formation with fringing reefs; they are probably slightly raised, though no definite evidence on this point is available. These three islands may well all be separated from the rest by over 2000 *f.* of water, but the main line so far as the soundings go would rather appear to be on a bank with at most 1000 to 1500 *f.* of water.

Reunion to the south is a volcanic island, 10,069 feet high, with fringing reefs in places, while Mauritius, also volcanic, 2700 feet high, has both barrier and fringing reefs, which were visited by Darwin. Tracing the line to the north Cargados Carajos is a crescent-shaped reef, awash, 30 miles long, in one place 4½ miles wide, with 7 low, coral islands, which appear to be washing away; it has a shallow bank extending 16 miles off to the west, but has in no way begun to assume an atoll form. The bank known as Nazareth probably extends down with shallow water (under 50 *f.*) and includes the last-named, giving a total length to the bank of 280 miles; the shallowest sounding is 14 *f.*, but the whole is ill-surveyed; there does not appear to be any deeper central part. The Saya de Malha, 150 miles further north, consists really of two considerable banks which are probably not separated by more than a few hundred fathoms from the last, as comparatively shallow soundings extend out from each for a long distance. The northern bank, 75 miles long by 23 broad, has a ring-shaped reef, about 12 *f.* deep (shoalest water 5 *f.*) with a central basin of 40 *f.*, while the southern is 140 miles long by 120 broad, with a rim to the N. and E. at 12 *f.* but only a little shoaler (25 *f.*) to the S. and W., and a central basin about 50 *f.* deep, a great bight in one place running in from the S. with 60 to 70 *f.* The two banks are remarkable for the great breadth of their rims, about 7 miles in the N. bank and 12 miles in the southern. A further small bank to the S.E. has one sounding of 57 *f.* in the centre and rim 25 *f.* deep.

The Seychelles lie about 200 miles N.W. of the last, with no bottom soundings in the channel between. They consist of ten high granitic islands, mostly with fringing reefs, on a bank 35 *f.* deep, 200 miles long by 120 broad. The northern outliers, Bird and Dennis

this section was obtained. Most of the surveys of isolated islands in the regions comprised in this and the next section appear to have been made by Admiral Sir W. Wharton, F.R.S., a most expert and careful observer. For information on Madagascar consult "Madagascar, Mauritius and the other East-African Islands" by Prof. Dr C. Keller, 1901, who gives a full list of references.

[1] *Vide* "The Physical Features of Rodriguez," by Is. Bayley Balfour, *Phil. Trans. R. S.*, vol. 168, pp. 289—292, 1879. The raised coral-rock is described as forming large, coralline, limestone plains of inconsiderable elevation. Prof. Bayley Balfour proceeds:—"The existence of these masses of coralline limestone indicates clearly a former lower level of the island, and the evidence of raised beaches confirms this. But a consideration of the coral-reefs points as clearly to a time when the island stood at a higher level. The present coral reef fringes the coast, extending about 3 miles on the south-west side, but coming close inshore on the east. An older reef, however, exists, now quite submerged in some places to a depth of over 90 fathoms. Upon it the present reef rests, and it extends westwards nearly 15 miles from the present coast, while to the east it stretches about 6 miles. We have thus proofs of great and intermittent oscillations of the level of the island." I may be permitted to point out, that it is *assumed* that this submerged reef is of coral formation. Its contour corresponds, so far as it is known, neither with existent fringing, nor barrier reefs. Its origin is probably rather to be traced to the former erosive action of the sea on a volcanic coast.

islands, are both of coral formation with no evidence of change of level. Platte island to the south lies on a bank, 17 miles long, separated by a channel, 25 miles wide; it has a low coral island, apparently on a reef awash, having a lagoon. Coetivy, 60 miles S.E., is a low coral island with sand hills, $5\frac{3}{4}$ miles long, by $1\frac{1}{2}$ broad, on a bank of about twice the size; near it and in the dividing channel towards the Seychelles are several other banks not properly surveyed. Continuing the main line to the S.W., separated from the Seychelles by a 22 mile channel with 1150 *f.* of water, is the Amirante bank, running 89 miles N.N.E. and S.S.W., varying in breadth from 5 miles at the north end to 23 miles at the south. There are nine principal reefs and islands, which tend to lie near the edge of the bank; none of them attain a height of even 20 feet. St Joseph and Desroches are atolls with soundings of 2 and 17 *f.* respectively in their lagoons, the rest being mostly round reefs, drying all over at low tide, with mere sand cay islands. Separated from the last by a channel, 46 miles across, with one sounding of 952 *f.* nearly in the middle, are two reefs, Alphonse and Francois; the former is an atoll with basin 10 *f.* deep, and the latter a reef, $8\frac{1}{2}$ miles long by 5 broad, with two islands, drying in patches, a little hollowed in the centre, but not enough to form a definite lagoon.

3. Chagos Section.

The Chagos Archipelago differs from either of the preceding sections, in that all its islands and reefs are of coral formation alone, hence bearing a much closer comparison to the Maldives. It lies almost in the same latitude as the south of the Seychelle group, but 600 miles further eastwards than that line of reefs; no soundings exist between. The group covers an area of about 170 miles north and south by 110 miles east and west, and is formed by five atolls, three atoll banks and three other banks of no very determinate shape; there are no bottom soundings between the different atolls and banks, a line of more than 150 *f.* being seldom used in Moresby's time (1835), the usual being about half this.

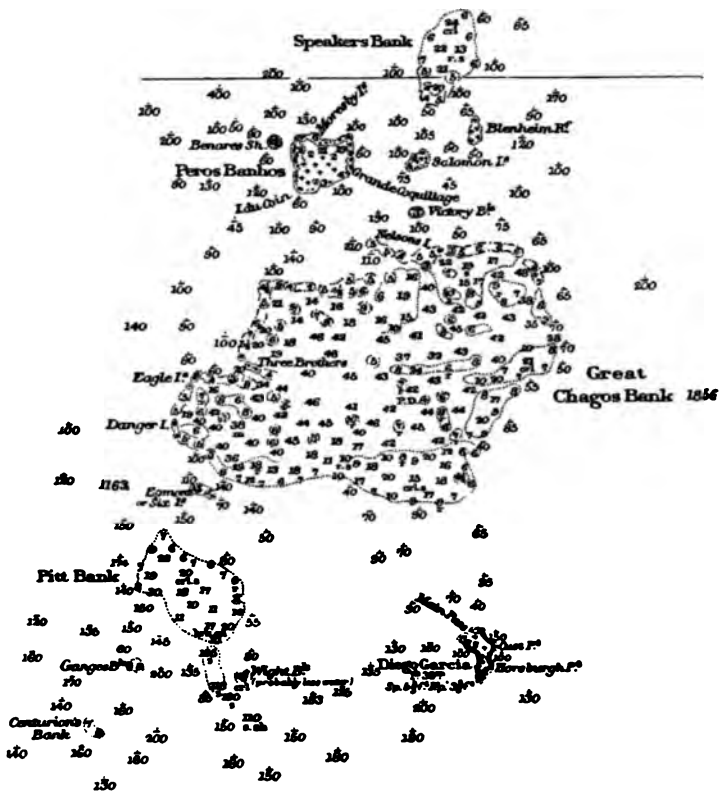

Fig. 4. Chagos Archipelago. (*From the Admiralty Chart.*)

To the S.S.W. lie three banks:—Centurion, 5 miles long by 2 broad, rim 7 to 10 *f.* deep, a single sounding of 14 *f.* in the central basin; Ganges, 4 miles long by 3 broad, rim 8 to 12 *f.* deep, a single sounding of 12 *f.* in the centre; and Pitt,

26 miles long by 16 broad, rim varying with 6 to 12 *f.* of water, very imperfect to the south, inside a shallow basin at about 20 *f.* with a few soundings up to 24 *f.* Egmont atoll lies between Great Chagos reef and Pitt bank; it is perfect in shape, 5½ miles long by 2 broad, with only one passage to the north, six islands to the south, lagoon 10 *f.* deep. S. by E. from Great Chagos lies Diego Garcia, another atoll, completely surrounded by land to the south, but with three passages (3½, 3½, and 6 *f.* of water) to the north; it is 13 miles long by 6 miles in greatest breadth, lagoon maximum depth 19 *f.*, much shoaler to the south. This atoll was visited in 1885 by Mr G. C. Bourne, who subsequently gave an account of it. He came to the conclusion that the whole atoll had been raised a few feet[1].

The Great Chagos bank is of somewhat irregular shape, about 82 miles east and west by 70 miles along a line at right angles. It has one island to the north, described as rocky, and seven to the west. The reef can nowhere be described as awash, save immediately in the neighbourhood of some of the islands, but the line all round the bank is markedly shallow, forming a reef. The general depth of the latter west and north is about 6 *f.*, least 4 *f.*, while east and south it is about 10 *f.*, least 6 *f.* The lagoon basin has an average depth of about 44 *f.*, greatest depth in centre 48 *f.*; it is connected to the sea by twenty-three passages. The shallow, encircling reefs are between the passages, great broad flats, sloping in from their outer edges to a depth of 20 *f.*; some are obviously small atolls, having shallower water at the edges and deeper in the centre. Against the lagoon basin the 20, 30 and 40 *f.* lines are practically conterminous, the reefs down to 40 *f.* being as precipitous in their slope on this side as towards the deep sea. About sixteen shoals arise in the lagoon from the bottom in 40 *f.* to within 6 to 10 *f.* of the surface, a striking uniformity in depth with the rim. Although the atoll from the soundings would appear to have been well surveyed it is remarkable that there are in the lagoon no shoals between 10 and 40 *f.* in depth. Of the passages five have about 40 *f.* of water right through, while six others appear to have over 30 *f.*

North of Great Chagos the Victory bank, 4 miles long by 2½ broad, has a perfect rim at 3 *f.* with 18 *f.* of water in the centre. Peros Banhos is a perfect atoll with 27 islands, in shape nearly a square 13 miles across; the greater part of its reef is awash save to the S.E., where it is submerged by about 4 *f.* of water, but even here two islets rise above the surface. The lagoon has thirteen passages to the exterior and is much studded with shoals; its general depth is less than 30 *f.*, but one sounding of 41 *f.* is recorded. The whole atoll bears a very close comparison to some of the more southern ones in the Maldives.

[1] *P. R. S.*, vol. 43, pp. 440—461, 1888. Mr Bourne has informed me that masses of the conglomerate (or reef-rock) exist everywhere on the outer reef in pinnacles and buttresses, extending out from the beach between tide-marks. The stratification of these is stated to be horizontal. No coral-rock is built up thus above the low tide limit, so that these absolutely prove a change of level. Mr Bourne in his account bases his views rather on the horizontal stratification of "shingle rock," an agglomeration of broken corals, mollusc and echinoderm shells, etc.; this rock was probably originally a formation on the lagoon side of a reef awash, and it would be interesting to know more of its distribution. The observations on *Ocypode* I cannot admit as referring to a crab of this genus at all; as Mr Borradaile points out in his paper in this publication the crabs of this genus do not construct burrows lined with weed, and one species lives above tidal limits; the holes of shore forms cave in, and are made afresh after every rise of tide, not necessarily too in the same place. Mr Bourne's deductions on lagoon formation in general by solution do not seem to me to carry much weight. They are based on experience of one atoll alone and that of abnormal form, in that it is of considerable size but completely surrounded with land except to the north; the circulation of water in the south half of the lagoon, which is especially referred to, cannot be anything but inconsiderable as compared even to any atoll with reef only awash in several positions.

Salomon atoll to the east of the last is oval, 5 miles long by 3 broad, with eleven islands on the rim, which is awash everywhere save for a single passage to the north, which itself has a shoal of 1 *f.* in the centre; the lagoon averages 12 *f.* deep, greatest sounding 17 *f.* Blenheim reef to the E.N.E. of the last, 6 miles long by 2 broad, would closely resemble Diego Garcia, if the latter instead of land had only a reef, swept by the tides; its opening, however, lies to the south-west, and its lagoon has only 10 *f.* of water. Finally, Speaker's Bank to the north of the last two is an irregular oval reef, 24 miles long by 13 broad; depths of 5 to 7 *f.* are recorded right round its circumferential reef with 24 *f.* in the central basin.

4. Maldive Section.

As my remarks on the Maldives are mainly based on my own observations and soundings I shall defer them, together with those I may have to offer on the Laccadives, to a separate chapter. The most southern atoll of the Maldive group, Addu, lies due north of the Chagos Archipelago at a distance of 240 miles, and the latter group might well be considered to be a continuation of the Laccadive-Maldive line. There is, however, one sounding of 2500 *f.* so close to the centre of the channel between, that it is practically certain that there is no bank at about 1000 *f.*, connecting the Chagos, as assumed by Mr Bourne. Since to the north the Laccadive banks very closely approach the Indian coast, it is important to note that the 1000 *f.* line has been traced everywhere between.

The Indian Peninsula has practically no reefs of any sort; its southern part towards Ceylon partakes of the same formation as the north portion of that island. The latter has locally fringing reefs, mostly in bays along the south and north coasts; above these to the south a loose rock, composed mainly of fragments of coral, often forms broad flats, 3 to 4 feet above high tide, now being rapidly washed away wherever they impinge on the beach[1]. Near Dambula in the centre of the island I saw limestone hills, at least 700 feet high, which from their general contour I should judge to have been of reef-formation; the rock is now completely crystallised, all trace of organic structure being lost. The Jaffna Peninsula, the outlying islands and the northern part of Ceylon are all formed of raised coralline rock, which still retains most of its organic structure; the elevation, as I saw it, did not appear to me to have been more than 40 feet, if as much. A former land connection with India was clearly indicated, of which a reef, known as Adam's Bridge, between the islands of Manar and Ramesvaram, is the remains[2].

[1] These can be seen in numerous places between Matale and Weligama.

[2] See "Ramesvaram Island," by Edgar Thurston, Madras Government Museum, Bulletin 3, 1895; also *Report Brit. Ass.*, p. 400, 1900.

CHAPTER II.

METEOROLOGICAL CONDITIONS.

THE Challenger Reports, edited by Sir John Murray, have shown how important it is to consider the meteorological conditions of any region whose geography it is desired to study. In the "Introduction" to this work I have briefly indicated the great variability found in the topography of the different atolls of the Maldives. As the latter group together with the Laccadives extends from lat. 1° S. to lat. 14° N., it will be readily understood that the meteorological conditions must vary very widely over this great region.

In respect to coral reefs, winds and storms are usually supposed to be the chief factors in the formation of land. Dana[1] has pointed out that their distribution follows the isocryme of 68° F. both N. and S. of the equator. Semper[2] drew attention to the effects of currents in shaping reefs, a point which has subsequently been further emphasized by several naturalists. The eroding action of rain has been referred to by many authors, chief among whom is Prof. Agassiz, who has also laid great stress on the action of the sea and waves on all coasts in general, but on coral-shores in particular[3]. The subject then being of wide interest in respect to the formation of coral reefs and islands, I shall consider the meteorological conditions of the region without in this place examining minutely their effects. The following account is derived largely from personal observations and native information, with which I endeavoured to check the account in the "West Coast of Hindustan Pilot" (1893); I have also consulted the captains of various steamers, which regularly ply in these waters.

The **winds**, experienced in the Laccadives and Maldives, are those of the two monsoons, influenced to the north by the proximity of the Indian coast and affected in the south by the equatorial winds. The north-east monsoon becomes set in the Laccadives about the end of November and continues until the end of March; during this period a more or less northerly wind prevails together with long calms, but little or no heavy weather. The monsoon gradually travels down the Maldive group, becoming regular from N.N.E to E.N.E. in Male atoll early in January. It is ushered in by a fortnight of strong winds from north to east with heavy rain squalls. The monsoon becomes definitely set as far south as Suvadiva atoll before the end of January. It is felt too even in Addu (lat. 0° 40′ S.)

[1] *Corals and Coral Islands*, 3rd ed. pp. 108 and 335.

[2] "Animal Life," *Internat. Sci. Series*, chaps. VII. and VIII.

[3] *Vide* "The Islands and Coral Reefs of Fiji" (*Bull. Mus. Comp. Zool.* vol. XXXIII. pp. 1—167, 1899) and numerous previous publications.

from January to March, but the wind is here very irregular, veering at any time six points to either side of north-east. Heavy rain squalls are frequent during the whole of the monsoon in the southern atolls, but the wind, although often blowing very fresh, has little weight. Fine weather, little rain and calms may be expected at the same time to the north of Male atoll.

The south-west monsoon is not felt in Addu atoll, where the "Pilot" states that from May to December the winds are from west to south and S.S.E. with much rain and squalls. It is well set in the Maldives during the months of June, July and August; fresh gales with heavy rain squalls occur frequently from any direction within four points of south-west. The period in the Laccadives is rather longer, the south-west wind usually becoming definitely set towards the end of May and continuing regularly until September. As already mentioned in the "Introduction" it did not in 1899 commence at Minikoi until the second week in August, up to which time the prevailing winds were from west to W.N.W.

The months, which intervene between the monsoons, form in the Maldives a period during which winds from any direction may be felt. Fresh gales of short duration tend to come up, the wind commonly veering from the north or south, right round to east, or west. In April we experienced in the channels between Addu and Suvadiva, and between the latter and Haddumati, heavy gales from the west. During these intervening periods cyclonic storms or hurricanes are especially liable to occur in the Arabian Sea. I have obtained no record of winds of this force having been ever experienced further south than Male atoll. They occasionally sweep over Tiladummati and Ihavandifulu atolls, the last occasion remembered by the natives being in February about 24 years ago, when very great destruction is stated to have been wrought among the larger native vessels, many of which were at the time lying at anchor in the lagoons. As negative evidence of the absence of such strong winds I may refer to the fact that throughout the Maldives I have found no true negro-heads—actual parts of the reef—which have been thrown up by the breakers on to the reef-flat. Hurricanes visit Minikoi at intervals of about 12 years, but, their centres usually lying considerably to the north, they may practically be neglected as factors in shaping the original reef and land. The more northern parts of the Laccadives are, however, much affected. The effects of hurricanes in this locality are admirably described in the following account of one, which visited Kalpeni in 1847:—"The sea washed over the island, and the storm-wave carried away the very soil of the narrower parts. Of 1600 inhabitants 250 were washed away and drowned in that night, 100 to 150 died of famine and disease, about 450 remain on the island and the rest have dispersed themselves. Of a lakh (100,000) of (coconut) trees about 700 sickly ones are standing[1]." At Androt of a population of over 3000 only 900 were left after the same hurricane.

The **currents** are of course largely dependent on the winds and tide. The direction from November to March in the Maldives to the north of lat. 2° N. varied from north-west to south-west; the drift in the centre of the group averaged about 18 miles per diem during the same time. Although we experienced strong winds from the west during April in the "Equatorial" and the "One-and-a-half-Degree" channels, there was at the same time practically no current. The native skippers, however, will not start across either channel unless the wind is fairly strong and at least nine points off the direct line from

[1] "Report on the Laccadive Islands," dated 19 May, 1848, by W. Robinson, Esq., Madras, p. 76, 1874.

atoll to atoll; they then set a course about 12 miles to east or west of the atoll they subsequently hope to reach. With the south-west monsoon comes a change of current, which is experienced at Male about the middle of May, the set then being almost due east; the rate of the current varies with the wind of the previous day. During April and October little or no current is felt.

The currents in the northern part of the Laccadives are very irregular owing to the proximity of the Indian coast. This is especially the case in the south-west monsoon, a definite south-eastern set being often experienced almost reaching to Minikoi. However, the following data are given in the Admiralty Charts for the neighbourhood of the latter atoll:—

January	0—45 miles per 24 hours, N.W.
February.....	Various, any direction.
March.....	Various, any direction, often due N. or S.
April	10—25 miles per 24 hours, S. varying 4 points to E. or W.
May.....	Various, always southerly.
June	0—45 miles per 24 hours, S.E.
July.....	5—30 „ „ „ S.E.
August	0—45 „ „ „ E.S.E.
September ...	0—25 „ „ „ S.E.
October	10—25 „ „ „ E.
November ...	Various, 0—35 miles per 24 hours, W.N.W.
December ...	„ 10—25 „ „ N.N.W.

The maximum currents above are undoubtedly current + wind. Many captains of the great passenger liners, running to the east, do not make any allowance, based on the charts, but consider only the winds of the previous days in setting their courses. The "West Coast of Hindustan Pilot" makes the following statement (p. 363) in respect to the "Eight-Degrees Channel" between Minikoi and the Maldives:—"It will be prudent to keep nearer to Minikoi than to the Maldives, as the current sets to southward between the end of September and the close of the year. In the strength of the south-west monsoon, mid-channel is the best track, or rather inclining to the Maldives." It is scarcely necessary for me to point out, that this statement is seriously in conflict with the data of the charts. It serves excellently to show that there are no definite currents in the Laccadives, all sides of the atolls and reefs being probably washed equally at different seasons of the year.

The currents through the atolls in the Maldives are of great strength, as also in the channels between the atolls. A current of three to four knots per hour is by no means uncommon in the passages on the east side of the atolls in the north-east monsoon, and this was even exceeded in the channels through the leeward reefs. In the lagoon of Miladumadulu we experienced in the middle of December a current of 2½ to 3 miles per hour, against which we could make no headway. With strong easterly breezes—hence at least eight points off our track in both atolls—we made a course along the east sides of N. Mahlos and Miladumadulu, which, if accurately plotted, would show a series of loops, losing opposite the passages and gaining our easting again to leeward of the islands and reefs. To test the rate of the currents, I adapted Messrs Negretti and Zambra's river-meter by fitting it with a larger vane. With currents over 2 knots per hour it appeared to give fairly reliable results. I took a series of observations on the currents

near Male island during the third week of February, 1900, wind 2 to 4 Admiralty scale, regular never varying more than a point from north-east, depth 2 fathoms.

Position	Depth of bottom in fathoms	Number of Observations	Direction of Current	Current in miles per hour	
				Greatest	Least
Passage Male to Hulule	24	9	N. by W.	5·1	1·5[1]
" " Wilingili	10	9	S. by W.	5·3	2·3
" " Funadu	26	9	W.N.W.	7·3	3·1
Two miles due N. of Male	28	6	S.W.—W.	3·4	·8[1]
Channel N. to S. Male Atoll	245	4	W.	4·1	2·7

I also sailed twice up to the passage between Hulule faro and Furenafuri, finding currents of 3·7 and 2·1 knots into the lagoon. Of course all these currents were largely dependent upon the tide, but it is a most noticeable feature that the direction remained constant in spite of the latter, which hence only affected the rate.

The depth, to which the currents of the Indian Ocean extend, has never, so far as I am aware, been investigated. Yet in considering any theory of the formation of coral reefs it is a most important factor, requiring consideration. I may perhaps refer to a short paper by Admiral Sir W. Wharton on the "Foundations of Coral Atolls[2]," where he discusses in this connection the depth to which there may be motion sufficiently violent to move material.

I applied two methods of investigation to ascertain the directions of the currents, *i.e.* by examining the specific gravity and temperature of the water at various depths, and by means of a direction-indicator. Admiral Marakoff is the chief exponent of the first method, which he used to examine the currents of the Bosphorus[3]; the direction of the current is found purely by deduction[4]. I employed it in the channels round Male, mentioned above, but the differences were too small and variable for it alone to be a satisfactory criterion. It was useful merely as a check on my second method. In the latter I attempted to record the directions of the currents at any depth by means of a compass (made for me by Messrs Negretti and Zambra). The latter was quite open to the water at the side of its box, and could at any depth be jammed by a messenger. The whole was placed in the middle of a V-shaped vane, which swung freely on a central bearing, itself clamped on the sounding line. Immediately below the direction-indicator I placed my current-meter, which I fitted to swing freely, and at the end of the rope I attached a 20 lb. sounding lead. The compass gave uniform results, but the readings of the current-meter varied so greatly that I omit any further reference to them.

I carried out observations in the first place to ascertain, whether the currents were the same at all depths in the deeper passages of atolls, as from theoretical considerations I expected to find under-currents. I found as a result that there was no difference in

[1] Approximate only. I obtained my scale on the meter by means of timed floats, using for the purpose corked bottles, weighted with sand, with tiny flags, so that they should not be affected by the wind. It must be checked frequently as the amount of friction may alter greatly. Previously to this I had used the meter constantly in Minikoi lagoon.

[2] *Nature*, vol. LV. pp. 390—3, 1897.

[3] I had the pleasure of discussing this subject with Adm. Sir W. Wharton, Sir John Murray and Mr J. Y. Buchanan, before I left England. I am indebted to these gentlemen for much practical advice as to the work of the expedition. I am only sorry that I could not carry out their suggestions in their entirety.

[4] *Vide* "Le Vitiaz et l'Océan Pacifique."

any of the positions previously recorded round Male island, either at half-flood, or half-ebb from the surface to within 3 fathoms of the bottom, an observation I confirmed by the hydrometer. In the channel between N. and S. Male atolls the current was in the same direction down to 150 fathoms.

My second series of observations were to ascertain the depth to which the main oceanic currents extended and their behaviour on meeting with an obstacle. I made two examinations, the first at Minikoi and the second at Male[1]. A preliminary series of observations off the east side of Minikoi showed that the oceanic current was setting S.E. by E., and could be recorded usually down to a depth of at least 60 fathoms. Starting from Weli Gandola passage, I then ran a line of soundings out from the reef, on which I had affixed a pole. At the same time I took a series of observations on the direction of the current at the surface and at intervals of about 20 fathoms down to a depth of 120 fathoms. Fig. 5 shows my results graphically; it records my stations and the vertical

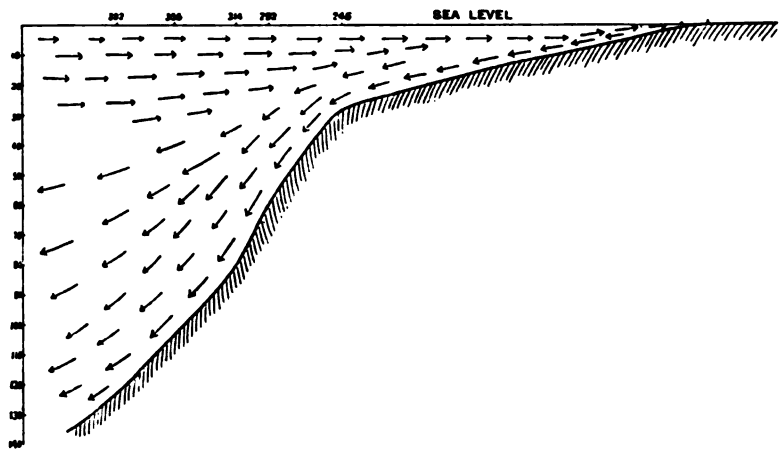

Fig. 5. Diagram to illustrate the behaviour of a current on striking a reef. The section is that of the outer slope off Weli-Gandola channel, Minikoi. Horizontal and vertical scales the same; the former is marked in yards, the latter in fathoms.

effects of the obstacle on the current. Horizontal plans would show the divarication of the upper current round the atoll, and the gradual merging into this of the lower current. I made two additional soundings between the reef and the first recorded in Fig. 5, but the rollers were so heavy that I did not attempt to use the indicator. A similar line, run off the reef of Hulule faro, the north point of Hulule bearing due west, gave similar results down to 80 fathoms, 500 yards from the edge of the reef. The records though were complicated by the proximity of the deep channel between N. and S. Male atolls.

[1] An apology is perhaps needed for offering these observations at all; they are not intended to be final, but may perhaps suggest to others, more happily situated than I am, the need of investigating the matter fully. My work, indeed, at Minikoi was meant to be experimental to test my apparatus. I proposed subsequently to investigate the point fully in the Maldives, but I was unable on account of illness to make more than a preliminary series of observations off Hulule.

I have in Fig. 5 represented the reef in its low-tide condition, when it is practically awash. Undoubtedly the surface current to some extent would be accentuated, and pass over the reef at high tide. It would be checked, however, by its friction on the reef, so that it would not probably gain greatly in strength, and hence the additional amount of water passing over any reef would be relatively small. In Minikoi during four nights, when I was anchored close to the reef, I never recorded a greater current than 2·4 knots per hour, although taking observations every hour. The backwash outside the reef, which appeared to be strongest close to the bottom, is of interest, as it might well carry out any coral or nullipore detritus from the reef and be the chief agent in extending its foundations further and further seaward. The depth, 20 to 60 fathoms, where the steep slope commences off most oceanic reefs, may well be the critical point for the oceanic currents off those reefs. Speculation is, however, premature until these observations have been confirmed, and more exact results have been obtained.

Tides are of course at all times largely influenced by the prevailing winds and currents; they are hence very irregular in the Maldives and Laccadives. At Minikoi I found a rise of about 5 feet 9 inches at springs and 3 feet 6 inches at neaps; at Addu the rise is only about 4½ feet at springs. In the south-west monsoon the flood commences extremely slowly, rises rapidly, and as slowly attains its maximum, at which it may hang for some time; the ebb, when it has once commenced, is more regular. In the north-east monsoon both flood and ebb pursue an even course. The flood always appears to set to the east and the ebb to the west. The latter at Minikoi in the south-west monsoon is almost invariably the longer in the proportion of about seven to five. There is, however, very considerable variation in accordance with the strength of the winds, and I have even observed the above proportion almost reversed; further it alters with the time of high water. The monsoon winds commonly moderate after the heat of the day during the night. Hence in the south-west monsoon the obstruction they form to the fall of the tide is not so great as in the daytime, with the result that the lowest tides occur in the early morning (high water, full and change, in the lagoon at Minikoi being about 10 h. 30 m.). In the north-east monsoon the winds assist the falling day-tide, and the evening tides are hence the lowest. This, however, is in no sense a complete explanation, as during dead-calm weather in the Maldives with no appreciable oceanic current I found that the same phenomena are nearly as strongly marked. The difference between the rise and fall of the morning and evening tides at springs is often in heavy weather as much as 2 to 2½ feet. On one occasion towards the north of the atoll of Minikoi the morning tide rose 7 feet 5 inches, while the evening tide did not show more than 4 feet 7 inches; it was blowing at the time a gale from the south-west.

The **rainfall** varies, increasing from the north to the south of the groups. At Minikoi its total is about 100 inches per annum, the greater part of which falls during the first month of the south-west monsoon. During the rest of the year, especially in December, heavy showers of short duration are not infrequent. Vegetation increases in luxuriance from north to south in the Maldives. At Addu there is no dry season, and the fall probably reaches a total of about 150 inches.

The **temperature** in the shade varies generally between 70° and 90° F., both day and night. For ten days at the end of February, 1900, it did not fall below 85° either by

night or day; such temperature is, however, very exceptional. The wet and dry bulbs are never far apart, and they commonly approach within 1° of one another during the south-west monsoon. The temperature of the sea varies greatly from year to year. The Admiralty Charts for the region of Minikoi give February 82°, May 86°, August 81° and November 84°. My observations for the four months I spent in this atoll were, expressed in round numbers, June 87°, July 84°, August 83° and September 84°. The maximum and minimum daily temperatures seldom varied more than 4° at depths of 4 to 8 feet; the observations, recorded above, are the mean of these. The temperature outside the reef and within the lagoon never varied more than 2° F.

[NOTE. Mr Forster Cooper on reading over the above chapter has offered me the following observations in respect to his cruise in March and April, 1900:—"In my journey through the atolls of South Male, Felidu, Mulaku, Kolumadulu and Haddumati I experienced only north-westerly winds with the exception of a due easterly gale, lasting three days, while I was in the south of Felidu atoll (March 12—14).

"Little current was noticeable during the cruise within the encircling reefs of the atolls, but in the dividing channels it varied usually between 2½ and 3 knots per hour, setting westerly. In the channel between Kolumadulu and Haddumati of Veimandu island the current reached 6½ knots per hour. It appears in the north-east monsoon to be always very strong in this channel; a native boat was a few years ago carried completely away, eventually reaching the African coast near Zanzibar."

The currents of either monsoon tend to run very strongly up and down the Maldive chain. As above shown, they reach to a considerable depth, and naturally tend to be much impeded by the banks. A strong current would be expected in the Veimandu channel, the N.E. horn of Haddumati directing the down current in this direction.

Capt. Pigott, R.N.R., S.S. "Vasna," B.I.S.N. Co., informs me that on the night of June 25th, 1899, he experienced a set S. 51° E. of 34½ miles in 12½ hours off the east of Miladumadulu and Tiladumati atolls. The weather was fine and settled, with a light westerly breeze, the sea calm with a long low swell from the south-east. The course was N.b.W., Mafaro at 4·20 p.m. bearing 12 miles due west. In the middle of the "Eight and a Half Degrees Channel" the current was setting about ¾ knot per hour due E. This observation shows very admirably how the current washes around the banks.]

CHAPTER III.

THE ATOLL OF MINIKOI.

SECTION 1. GENERAL.

Minikoi atoll (Fig. 1) is of a more or less oval shape, somewhat pointed to the north-east, where there is a narrow channel into the lagoon with 2 to 2½ fathoms of water. This passage is further broken by a shoal in the centre, showing clearly the continuation of the reef. The latter is for the rest perfect, and can in moderate weather be traversed everywhere on foot at low spring-tides. Three boat-passages exist to the north-north-west, available at half tide, but the importance of these must not be magnified, as they are regularly cleared by the inhabitants. The greatest length of the atoll is 5 miles and breadth 2·9 miles; the circumference is nearly 13 miles and the lagoon occupies an area of about 6 square miles.

The position of the atoll has already been seen. It suffices here merely to draw attention to its isolation, arising as it does probably within two miles from a depth of 1100 fathoms on every side except to the south-south-west. In the latter position a ridge at a depth of about 950 fathoms appears from the charts to connect Minikoi atoll to the Maldive group. Unfortunately no proper sections were run when the atoll was re-surveyed in 1891, and I had not the means to make a proper series of soundings. Indeed the weather was too bad during the greater part of my stay for boats to get out except to the north and east. In these situations the slope commences with a sudden drop from the reef to 2 or 3 fathoms, the bottom consisting of rounded buttresses and masses of coral-rock. Local variations due to shallow platforms occur, but the fall is generally fairly even for 100 to 350 yards, where a steep commences at a depth of 30 to 50 fathoms. To the east-north-east of Kodi point this shelf is more extensive, the greater part having a depth of 35 fathoms, forming a possible anchorage in the south-west monsoon. The further slope here is more gradual, and the steep less defined, indicating the trend of the submarine elevation, on which the atoll is founded. The steep is probably similar to that of Funafuti and other atolls, a few yards giving no bottom at 120 fathoms (Fig. 5). I did not sound deeper, but the chart indicates that a more gradual slope soon commences down to the encircling depth. The first slope to about 40 fathoms is notably broader to the north and west than to the south and east; in the latter position no two sections are the same. In Fig. 5 a section off Weli Gandola passage is represented. The bottom

would appear to be extremely rough, great masses of rock, off which the lead drops sometimes for an additional 3 to 5 fathoms.

The chief island, called Minikoi throughout this paper, extends from the north point right down the east and south sides of the atoll for a distance of six miles. It is only about 50 yards broad to the north, but gradually increases further south, attaining at its centre a breadth of 750 yards. In the latter position a prominent point, Mou-Rambu,

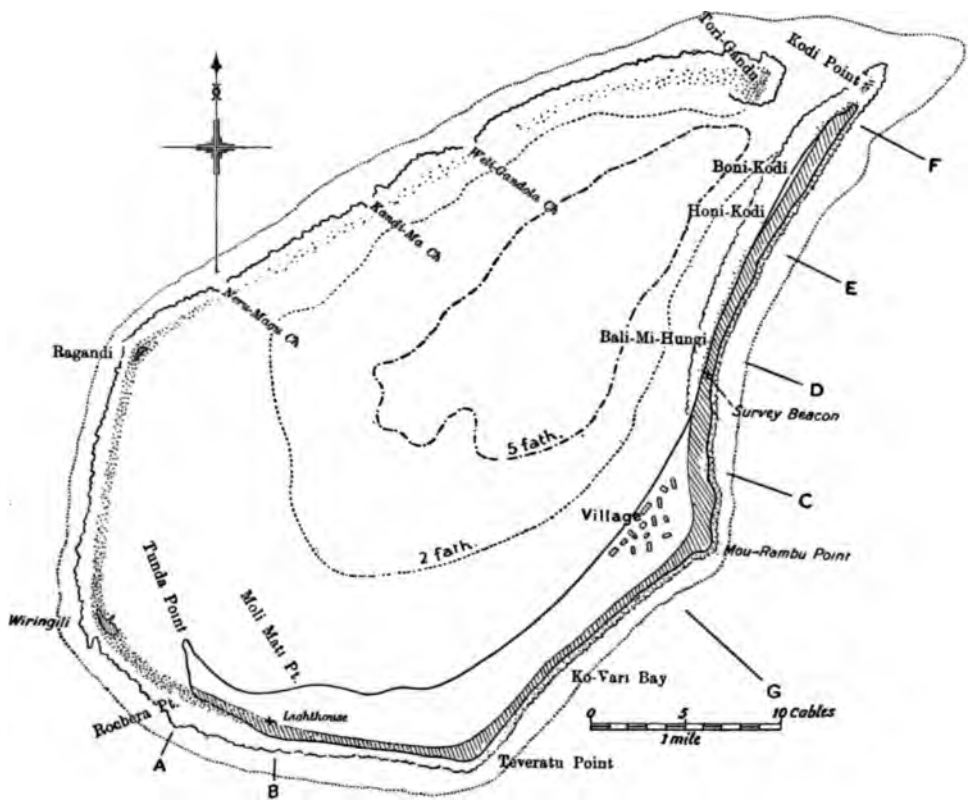

Fig. 6. Minikoi Atoll (*slightly altered from the Admiralty Chart*). The rocky area of the land is shaded, the boulder zone dotted, and the 100 fathom line is shown. *A—G*, positions of the sections in Fig. 7.

extends to the south-east, and on the opposite lagoon-shore the only village of the atoll is situated. Proceeding southwards Minikoi varies in breadth between 300 and 600 yards, ending with a small horn, extending north for 200 yards into the lagoon. This horn is the only bank in the atoll, which may be supposed to have been formed by sand and detritus swept over the reef.

On the seaward face from the north end to Mou-Rambu point the reef is very narrow, and indeed can scarcely be said to exist. It then gradually broadens to the west point of Minikoi island, where it passes into the reef-flat of the west and north sides of the atoll. The island itself merges into a well-marked boulder zone on the same reef, on which the small island of Wiringili arises at a distance of half a mile. The reef retains

a characteristic broad reef-flat and rough zone for one and a half miles to a small rocky patch, Ragandi island, extending from thence in an east-north-easterly direction to the deep lagoon passage. In the latter part the reef is much narrower and considerably broken up, the boulder zone scarcely existing in some places.

SECTION 2. LAND.

The surface of Minikoi island (Fig. 6) is sharply divided into two areas, an outer, covered on the surface with large, loose, coral or rock masses, and an inner, with sand. The line of junction is quite distinct, in some places a slight dip, in others an abrupt step down to the sandy area. The rocky area fringes the island on its seaward face, varying up to 150 yards in breadth near the village. Where the island is less than 100 yards in breadth, it alone is traversed in a section. The whole of the northern two miles thus belongs to this area with the exception of a narrow sandy patch against the lagoon at Boni-Kodi. South of Mou-Rambu point the rocky area narrows somewhat, especially in Ko-Vari Bay and between Rocbera and Teveratu points, where it is in places only 70 to 80 yards broad, being indeed generally less than 100 yards.

In the rocky area the surface is covered with masses of coral or limestone, some round, others flat slabs, weighing up to 1 cwt. or even more. To the north of Mou-Rambu they are much larger than to the south, where blown sand also has to some extent intermingled. All the surface masses are pitted, and eaten into sharp points by the rain, which rapidly drains through them. No soil has formed, and layer after layer of blocks can be removed, until a firm bed conglomerate within tidal limits is at last reached. The whole is covered with timber, or woody herbage, the roots of which extend down even into the conglomerate. On the surface the masses have much the same appearance, allowing for rain, as they have on a tidal beach. If the outer blocks however be removed, *Madrepora*, *Pocillopora*, and other branching corals are found with their stems still unbroken, while massive species have their calicles and septa even yet entire, *absolutely negativing the possibility of a beach-origin for the rocky area.*

Speaking quite generally, the island attains its maximum height toward the seaward side, and slopes gradually to the lagoon. To ascertain the height accurately, I ran six sections across the island, leaving one broad gap between the lighthouse and the village, where the growth of coconut and other timber was too dense to allow of rides being cut. Even there, however, I obtained a few partial sections in from the seaward beach. The inner part of the reef-flat, where the latter exists, lies at the mean low-tide level, and all heights are taken as above this, since it must be regarded as the upward limit, to which the various organisms can build their reef. The sections give the following measurements (Figs. 6 and 7).

Section	Breadth of Island in yards	Greatest Height	Height at Centre of Section	Greatest Height near Lagoon
A	370	9 ft. 0 in.	3 ft. 11 in.	5 ft. 0 in.
B	495	12 „ 3 „	5 „ 11 „	5 „ 8 „
C	375	12 „ 8 „	3 „ 8 „	10 „ 3 „
D	103	14 „ 9 „	13 „ 0 „[1]	10 „ 0 „
E	80	13 „ 6 „	9 „ 6 „[1]	7 „ 4 „
F	107	14 „ 8 „	13 „ 1 „[1]	12 „ 0 „

[1] Approximate only.

In most of the sections the greatest height is close to the top of the seaward beach, but in *F* it lies 66 feet back from this position. A seventh section *G* (Fig. 7), opposite the village in Ko-Vari bay, gave an elevation of 19 ft. 3 in., close to the sea, and heights up to 20 feet occur on both sides of Mou-Rambu point, decreasing northwards to a general height of 14 feet and to the south of 12½ feet. The abnormal height of the beach continues to Teveratu point right along Ko-Vari bay. At my first examination I did not deem this exceptional, since on this part, especially supposing the atoll at one time a reef awash,

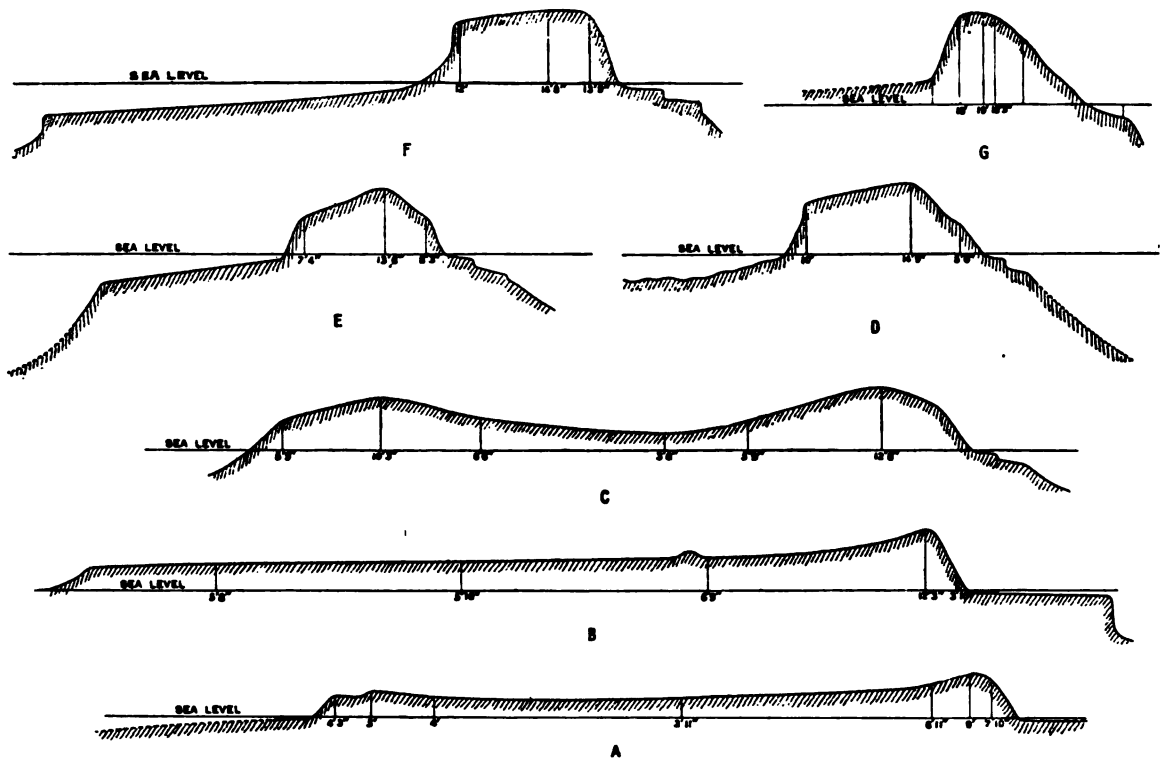

FIG. 7. Sections across Minikoi (see Fig. 6). In every case the seaward face is represented to the right. *Vertical scale 8 times the horizontal.*

masses of rock and coral would, I considered, naturally tend to be piled up in each monsoon. Inside this ridge the surface of the land had been, I saw, much lowered by previous generations of the natives for planting purposes, and also to form pits for macerating the coconut husks for coir[1].

My attention being especially drawn to this, I re-examined the whole carefully, and dug a number of pits, coming to the conclusion that the ridge may have been broadened by the above means, but that its height is due to absolutely natural causes. *An elevation then, allowing for rainwater denudation, of at least 24 feet demands explanation.*

[1] This hollowing out of garden land—*totam*, as it is called—is common throughout the whole of the Laccadives for *ragghee* (grain) growing, and also for bananas and yams. I did not meet with it in any part of the Maldives. Coir is rope made from the fibre of the coconut husk.

Fig. 1. Sea-beach at low tide near Kodi point, Minikoi, with S.S. Thrunscoe ashore

Fig. 2. Lagoon-beach at low tide near Kodi point, Minikoi

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A glance at the sections shows that the outer beach[1] increases in steepness from south to north of the island, from *A* to *F*. A certain amount of sand occurs at the base of the beach to the south, and the whole slope is quite regular.

North of Mou-Rambu there is no sand, and the beach is formed entirely of large blocks of stone (Pl. I. fig. 1). It cannot here be a formation simply piled up by the breakers, since its slope is gradual only at the base, ending above may-be precipitously, or even with a small overhanging cliff. Recently living coral masses are rare among the blocks; no pumice occurs; the greater part indeed is formed of the same weathered blocks, which strew the rocky area of the island, smoothed somewhat perchance by the waves and spray. The before-mentioned conglomerate crops out along the whole length of the seaward beach. Vegetation extends in many places right up to its summit; often the roots of the trees are exposed, and here and there the trees themselves have fallen. All these points are very marked along the eastern face, and further only the remains of a former wide path of flattened stones are now to be found. *Indeed there can be no doubt, but that the waves are slowly and surely encroaching on the land.* Between Mou-Rambu and Teveratu points the erosion is still visible, though the rate is less. On to Rocbera point the action is not so clear, but the masses of conglomerate at the base of the beach and the almost complete absence of reef masses, thrown up after the heavy gales of the south-west monsoon (which I saw), lead me to believe that the same action is still proceeding. From Rocbera towards Tunda point there can be no doubt as to the washing away masses of conglomerate of large size cropping up near the first point with a marked cliff on the beach above. It is, here, however, due mainly to the strong currents and continual rollers, which in the south-west monsoon at high-tide sweep across the reef and along the beach.

Round the north, or Kodi point, the beach has a definite cliff above of 4 to 7 feet, and indeed it is formed mainly of the masses which have slipped from this with a little sand below high-tide mark. The line of the island is shown by isolated masses of conglomerate, which extend northwards on the reef (Pl. II. Fig. 1). A break occurs first, the reef-flat extending across from the sea to the passage into the lagoon. Then follow the conglomerate masses, more or less in ridges, which gradually tail off to the point of the reef. Formerly a few coconut trees grew on these masses, but now all except one small peak are covered at spring tides.

Along the lagoon side of the island, from the north point to the Survey Beacon, the cliff continues. At the north it varies up to 10 feet in height above its detritus, which together with sand washed up by the waves adds about 3 feet more to the height of the land above the mean low-tide level (Pl. I. Fig. 2). Conglomerate crops out to a height of 2 to 3 feet in the face of the cliff, but the latter consists for the most part of coral masses, similar to those which cover the rocky area of the island. These blocks, following the usual mode of growth of most corals in shallow waters at any rate, tend to be flattened; they lie horizontally in the cliff, and have no trace of any dip in any determinate direction (Fig. 8). The rocky beach about a quarter of a mile from the north end is broken by coarse sand with a definite cliff above, the island itself

[1] I have throughout avoided the use of the term "hurricane beach," as I think that it is due to a misconception of the mode of origin of most islands of atolls.

broadening slightly. Southwards again the rock reasserts itself with smaller coral masses and a lower cliff (seldom more than 6 feet) with perhaps a tendency to form a greater talus. The basal conglomerate masses too are generally smaller and of lesser height. Coral slabs from the lagoon do not add at all to the beach, and even seaweeds and sand do not accumulate except in a small bay near Kodi point, protected by spurs of rock on either side. The shore especially at Boni-Kodi is strewn with fallen coconut and other timber. An old pilgrimage path, extending to the shrine of a *Said*, close to Kodi point, only exists now here and there. The end wall of a long house, which formerly stood at Bali-Mi-Hungi, the leper settlement, alone stands. *The sea is rapidly regaining its sway.*

Fig. 8. Cliff against the lagoon near Kodi point, showing conglomerate masses at base. (*From a photograph*).

Along the sand area the cliff retains its position almost down to the village, and the beach is strewn with coconut trees. Gradually however the slope broadens, and its summit opposite the village is almost washed by the succeeding waves of the high spring tides. At Moli-Mati point its breadth reaches a maximum, 50 yards across between tide-marks, the land above gradually attaining a height of 2 feet more. The high-tide limit is shown in the south-west monsoon by a line of green algae and sand washed up by the waves. Shells in the beach are rare, the whole being formed of extremely fine, almost impalpable white sand, the washings of many reefs. No decaying vegetable matter is seen to relieve the whiteness, save the single line left by the preceding high tide, all such being quickly seized by Ocypod crabs and drawn into their burrows.

Above the high-tide limit the height of the land is gradually increased by sand blown up the beach at low tide. A few yards back herbaceous plants commence to grow, soon giving place to the typical bushes. The natives quickly follow, and plant coconuts, which may be seen gradually rising in height further inland. *The land, indeed, is here rapidly gaining on the lagoon.* Still further on, towards the inner side of Tunda point, the cliff and fallen trees reappear, where, if anywhere, it would be most natural to expect a backwash and a piling up of sand to form fresh land.

Here in Minikoi we have a typically situated island, of an atoll with the reef continuing unbroken at its west end, round which the tide surges with considerable force. The current should sweep sand and mud off the reef, should build up a shoal into the lagoon, and should carry the point of the island along this. It is essential to see if this

is what is really happening, since Dr Guppy[1] has brought forward a great mass of circumstantial evidence to show that it is in this way that secondary atollons are formed reclaiming ultimately large areas from the sea. The southern half of Minikoi too would seem to be absolutely similar to that of the Cocos-Keeling atoll described by Guppy. The rocky seaward rim of Minikoi extends at Rocbera point directly into the boulder zone of the reef, many long masses of rock more or less undermined marking its transition. The rocky area before this had from the lighthouse westward been gradually narrowing, and at the point the beach has a small cliff above with undermined or fallen bushes, which conclusively prove its washing away. Just behind Rocbera is a small marsh or *kuli*[2], covered with reed, its floor below the high-tide limit. Tunda point does not extend directly into the lagoon, but a little to the north-west. Round it the water is deeper close to the shore than further out towards Wiringili, and the greater part of the bottom here is covered with a branching species of *Porites*, right to the base of the beach, some being thrown up at the point. North of the *kuli* all is sand, the same indeed as forms the lagoon beach at Moli-Mati point. If some of the beach sand between Rocbera and Tunda points (not a mere surface scraping) be sifted to remove the smallest particles, it will be seen to be essentially the same. The sand carried over the reef in this position is largely foraminiferal, while that on the beach is formed of finely triturated coral particles. *It follows then that Tunda point must originally have been a lagoon formation. Behind this point on each side the shores show a marked loss. The land is gradually narrowing, the sea will sooner or later break across, the corals round the point will be silted up and killed; finally the whole will be washed away. Moli-Mati will probably, unless man interferes, form such another point in the not very distant future.*

Before discussing the formation of the conglomerate, it is important to consider the action—as deduced from observation—of the various agencies, to which a reef-rock, such as I consider this rock to be, may be subjected above and below the sea. A reef, freely exposed to the sea, may be compared in structure to a sponge, a series of hollow cavities joined together by canals. Corals grow leaving cavities and spaces, which become silted up to some extent with sand, composed of their own fragments and Foraminifera. These spaces are next bridged over partially by means of the corals themselves, but more particularly by *Lithothamnion* and *Polytrema*[3] (Foraminifera). When the cavities are once completely closed in from the sea by organic growths, there is practically no circulation of water in them, causing any change; boring and other organisms are killed, or depart for the more surface growths. As long as there is a circulation of water, a continual solution and redeposition of the lime[4] goes on. The sand, being loose, is ground down into fine particles, which naturally, presenting a relatively greater surface, would be first dissolved. The deposition would tend to occur within the pores of the corals, where the change of water is less, and there is a fixed support; the lime deposited follows the crystalline form of the coral. So long as the coral skeletons are protected by organic growths, none of these changes can go on, but boring

[1] "The Cocos-Keeling Islands," *Scot. Geo. Mag.* (1889).

[2] I propose to employ this term for all such marshes of atoll islands, borrowing the name from the Maldivan, whence is also derived the name *atolu* or atoll. The term appears to me preferable to *barachois*, which is used for such by G. C. Bourne in speaking of Diego Garcia (*P. R. S.*, vol. 43, p. 442, 1888).

[3] This form gradually increases in importance to a limited depth.

[4] For the sake of brevity I use this term throughout instead of calcium carbonate, or bicarbonate.

organisms, especially sponges, may work destruction. If the growth of the reef be vigorous, the whole action of the latter may be neglected, the corals not being seriously weakened. If on the contrary the conditions are unfavourable, whole masses of coral may collapse with the slightest superincumbent weight into small grains, giving, with the solution and redeposition of the lime, great bricks, as it were, of structureless rock. Other skeletons suffer with those of corals, but the solvent action is invariably more and the boring action less pronounced.

Above the sea- and tide-marks the first action on the same reef-rock is the solution by the rain of the softer parts, sand, nullipore, etc.[1] Some of the water escapes carrying its lime, but a considerable portion percolates into hollows and is dried up, its lime serving to consolidate the sand, etc. The water attacks the corals from the base, where they are weakened by boring organisms, breaking them off and causing a sinking of the whole surface, portion by portion. This continues until the crevices below are to a large extent filled up with sand and fragments, more or less consolidated together. There results finally a solid surface, strewn with coral blocks, which have less rapidly dissolved. A few chambers may remain in the rock; they either existed as such from the original reef, in which they were closed in, or were subsequently dissolved out owing to the rain having ready means of access and escape.

Between tide-marks the action is more complicated by the wetting and partial drying of the rocks by water, containing a large amount of calcium sulphate in solution, and further charged with lime from the neighbouring shore and reefs. First the surface, exposed to the tide, has its pores to some extent filled up by sand particles. It further hardens, and becomes thoroughly indurated with lime, precipitated from the water, which dries on the surface after each ebb. Yet withal solution is quite marked; the waves stream off by tortuous channels worn in the sand and nullipore formations between the harder corals, which, if branched, are left as an upstanding forest of stems. Behind the surface loose sand becomes more consolidated than where there is rain-water action alone. The solvent action within the masses, save a little due to the rain, is inconsiderable, and the whole differs very little from the original reef, except in its better consolidation and the filling in of some of its interspaces.

The conglomerate in Minikoi is found everywhere at the base of the outer beach, especially at the points. Immense masses occur in the beach on the lagoon side of Kodi point (Pl. I. fig. 2), and continue in smaller pinnacles along the same shore, as far as the rocky beach extends. The masses are much pitted and very rough on the surface and of a slate-grey colour; they consist of a consolidation of corals, nullipores, shells, etc. Between tide-marks the scour, sweeping the sand and pebbles to and fro, undermines and finally precipitates the masses, to wear themselves beds perhaps in the rock beneath, to which they may become consolidated. It follows then that no results can be obtained by the examination of the smaller masses in respect to the position of the corals, etc., of which they are composed. The large lagoon masses near Kodi point are of rough surface with their corals freely exposed (Fig. 9). *Madrepora* is by far the most abundant genus

[1] These deductions are largely based on my observations on indubitably raised rocks in the Fijies, but more particularly in the northern districts of Ceylon, the Jaffna Peninsula and the adjacent islands. See *Report Brit. Ass.*, p. 400, 1900.

represented, but *Pocillopora*, *Euphyllia*, *Pavonia*, *Astraea*, *Galaxea* and *Montipora* were also found. The modern facies or species of *Madrepora* grow from a central mass with branches radiating out over their upper surfaces. The central stems grow straight upright, vertically indeed, and are packed all over with corallites, possessing more or less raised calicles, which

FIG. 9. Conglomerate mass near Wiringili at low tide, showing the rugged appearance and undermining by tidal action. (*From a photograph.*)

give them a very rough appearance. The branches extend more and more horizontally from the centre outwards, but none grow downwards. The upper surfaces of the horizontal branches are similar to the central stems, but their lower are smooth, corallites distant from one another, calicles with no raised rims. The basal mass, in which the branches appear to be rooted, is formed by a filling up of the interspaces between the branches by a lighter corallum of open texture, a kind of coenenchyma. Such being the mode of growth of *Madrepora* it follows that this genus forms an excellent criterion by which to judge whether the conglomerate masses originally grew as such, or were otherwise formed, as by a beach consolidation (Pl. II. fig. 2).

On the pinnacles and masses the branches of the different facies of Madrepora *are much worn but generally still entire. Some of the colonies seem to be a little tilted, but most are clearly in the absolute position in which they originally grew*[1]. *Other genera of corals amply confirm the evidence of elevation, which this fact implies, and imbedded* Tridacna *shells with their open mouths in a horizontal position lend their support.*

It remains to consider the position in which the conglomerate was originally formed. The fine-grained structure of some parts shows the presence of nullipores, but the latter are never in sufficient quantity, allowing amply for denudation, for the whole to have formed part of the surface of a reef awash. At the same time spreading nullipores, of which there are indubitable traces, show that the rock must have been formed in a reef, freely exposed to the sea, and cannot have been built up in a lagoon. At Minikoi I was

[1] It occurred to me that the specific gravity of the basal mass might be such that the *Madrepora* would naturally tend to take up this position. I hence had a large number of colonies (about 30) placed on the reef near Teveratu point. The branches were broken off, the basal masses alone were left. They lay in every conceivable position, more indeed on the upper surface, as without its branches it became almost flat.

never able to approach a typical part of the reef from seaward[1], but in the Maldives at about three fathoms the bottom consists of great buttresses and masses with branching *Madrepora* and *Pocillopora*, massive corals here and there, and a considerable nullipore growth between. These coral colonies are for the most part small, the branches short and stout,—the usual condition near the surface, or in any strong current,—and somewhat resembling those of the conglomerate masses. Between the buttresses sand and a few boulders of coral, broken off the higher parts of the reef and rolled smooth, are seen, themselves perhaps to be built into the reef. Such boulders I have not found in the conglomerate, and their absence would indicate that the latter was formed both deeper and before the existence of any reef-flat to the atoll. *Indeed the conglomerate would seem to have constituted part of the original reef (which by subsequent growth fashioned the atoll of Minikoi) at a time antecedent to the formation of any definite reef-flat, and at a depth of at least three fathoms. The conglomerate then may be considered to prove conclusively an elevation of the atoll. Its summits are* 6 *feet above the reef-flat (the low-tide level) and, allowing* 18 *feet for the depth at which it was formed, there must have been an alteration of level of at least* 24 *feet.*

Returning to the condition of the whole reef at the time of elevation, if there were a broad reef-flat, no additional upheaval to that suggested above would be required to explain the height of the island in different positions. The boulders, which form the rocky area, lie more or less horizontally on one another, and are much rain-worn. If they had been piled up by the waves, they would show a definite dip, but their position is more in accordance with their being formed by the simple sinking of the surface owing to the solvent action of the rain, removing nullipores, sand and the softer parts. The height of the land-sections *D* and *F* is about 14 feet[2], and the elevation based on other considerations 24 feet, giving a sinking of 10 feet to the surface. Considering the heavy rainfall, the spongy nature of a reef, and the almost complete absence of evidence of nullipore growth in the boulders, this erosion of the surface would seem to me but reasonable. Allowing an average loss of half an inch in a century, ample even if the original reef were not solid, only 24,000 years since the elevation would be required. This period is perhaps more than sufficient for all the changes which have taken place in the atoll since its elevation, but is not synchronous with any known upheaval, such as might naturally be expected in the Hindustan continent, if such a change of level has taken place, as I believe, more or less at the same time throughout both the Laccadives and Maldives.

Let us proceed however to an examination of the sandy areas, so as to see whether they lend any support to the changes that have so far been deduced. I have already described the surface characters of this area with the exception of a small patch at Boni-Kodi, similar sand to which indeed forms a belt everywhere against the rocky area. It consists of coarse particles of all the organic skeletons, which assist in forming a reef, with larger rounded pieces of coral. It thus differs entirely from the fine sand of the lagoon shore elsewhere, resembling somewhat closely the sand at the base of the sea-beach of the south half of the island. I investigated its distribution by digging pits in section across

[1] For the reef characters in different positions see Sec. III. Such reef as exists between Mou-Rambu and Kodi points is not typical.

[2] I have not taken the greater elevation—19 feet—as found in section G, as I consider that there may have been along the ridge here a piling up of boulders, even land, at a time antecedent to the elevation.

the island and by examining all wells and native excavations. North of the village it practically extends from the old raised reef to the lagoon, but southwards it gradually decreases in breadth, giving place to the regular lagoon beach sand. Towards the rocky area more coral fragments occur, but the junction is sharply defined, while on its lagoon side it merges very gradually into the finer sand. The patch at Boni-Kodi forms a soft, very friable sandstone on the surface with loose sand beneath, apparently the crowbar finally fetching a hard rock. The amount of consolidation elsewhere is very varied, but at the mean high-tide level it commonly forms a loose sandstone, increasing gradually in hardness to the low-tide limit, below which soft sand succeeds and water is obtained, varying in sweetness with the distance from the sea.

Reef-flats without islands generally slope towards their lagoons for some distance, the hard rock gradually giving place to a coarse sand, which has been swept across the flat by the waves[1]. *The origin of this belt of coarse sand at Minikoi must have been, I think, the same, and its occurrence hence supports the view that the rocky area at one time formed part of a regular reef-flat.*

Remembering that the remainder of the sand is certainly of lagoon origin, it is of interest to remark that in some of my pits in it I found alternations of harder and softer sandstone, or loose sand. It was impracticable to trench across, but my pits were sufficiently numerous to warrant me in the belief that there is an irregular series of lines of sand-rock, more or less parallel to the lagoon shore with areas of loose sand between. I shall have occasion subsequently to point out that the formation of sand-rock is characteristic of beaches, which are washing away, or at rest. *Hence it may perhaps be deduced that there have been periods at Minikoi, when sand was being actively heaped up from the lagoon, alternating with periods of rest, or even of washing away.*

Beach-sand-rock at the present day crops out nowhere on the lagoon shores of the island. A little only is found at the west end and on the outer beach to the south. In Ko-Vari bay it fringes the beach against the reef, but it is doubtful whether its constituents did not rather form part of the original raised reef. The same remark perhaps applies to its presence elsewhere, but the point is immaterial, as no deductions are based on its occurrence.

The island of Wiringili is formed almost entirely of rock, much of its surface being bare. It is situated at one of the most exposed parts of the atolls, for the south-west gales are always those of the greatest force, and the reef outside it is narrow. The conglomerate rock forms a broad belt of masses and pinnacles at the inner part of the reef, many of them much undermined (fig. 10); they reach a maximum height over the reef-flat of 8 feet, and loose masses add an additional 2 or 3 feet to the altitude of the land. On the lagoon side of the island is a collection of small fragments of rock and sand. The erosion on the seaward face is very marked, but the rest of the island is protected by the conglomerate band.

Ragandi is a bare islet of conglomerate close to the edge of the reef. It is covered usually with loose boulders, thrown up by the waves, but the sea occasionally sweeps it quite clean, generally carrying away at the same time a wooden beacon, which crowns its summit. It is probable that in a few years no trace of the land will remain.

[1] Submerged reefs on the other hand are generally precipitous on all sides, and do not hence show such or indeed any transition to a sandy area.

CHAPTER IV.

THE ATOLL OF MINIKOI (*Continued*).

SECTION 3. THE ATOLL REEF.

The encircling reef of Minikoi in its different aspects may be considered as typical of the whole of the Maldive and Laccadive atoll-reefs. In a section three parts may be distinguished—the reef-flat, the rough or boulder zone, and the inner slope. The two former are to some extent sharply separated off, as their basis is a solid flat of rock, while the third may be entirely formed of loose sand. There is also the outer slope to the depths of the sea, but I have already referred to this in my general account of the atoll (Sec. 1, p. 27). I shall, however, recur to its characters in any position where it may appear different from the previous descriptions. On account of the variation it will be most convenient to sketch in the characters of the reef in several different situations in a traverse of the whole circumference of the atoll. In my account of the Maldives I shall as far as possible for description merely refer to the reef in different situations at Minikoi atoll.

Kodi point is essentially a sharp projection, the breadth being less than 100 yards from a depth of 1½ fathoms on either side. Owing to its situation by the lagoon passage the currents in and out of which, meeting with those along the seaward reef, form a whirl round the point, the sea breaks heavily on either side almost independently of the quarter from which the wind may happen to be blowing. Hence the two sides, experiencing almost the same conditions, resemble one another closely. The point of the reef projects about 1 cable (200 yards) from the land, and in its centre lies a series of conglomerate masses, 40 yards long, running parallel to the outer edge of the reef on either side. Taking a section across the centre of the point, one finds two or three little terraces on the outer or east side, each perhaps 12 yards broad and rising by a 2-feet step at its outer edge. They are studded with low pinnacles of the conglomerate, which also form a broken line at the outer edge of each. These masses increase in size and height inwards, and are of smooth contour, exhibiting externally no trace of their constitution. The whole surface between is covered with low green algae, and is completely destitute of sand and boulders of any sort; no corals grow, and only a few low incrusting nullipores are found towards the seaward edge of the outer terrace. Further seaward the whole bottom could be seen at the backwash, preceding each breaker, to be spread with red, white and pink *Lithothamnion* together with a few corals, principally small colonies of the most massive facies of *Pocillopora* and *Madrepora* (Pl. II. fig. 1).

Fig. 1. Reef from Kodi point, Minikoi, looking north

Fig. 2. Conglomerate mass at base of beach

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In the centre of the reef the rock masses are all much eroded underneath by the seas, which at high tide, breaking on either side, meet one another in the middle of the reef to rush along and escape at its north point. This central pinnacled flat is about 30 yards broad, and in places a few coral masses lie, some perhaps thrown up by the sea, but most eroded out of the conglomerate. Between the masses a few pits are found, from which the water does not escape, and in these flourish colonies of *Porites arenosa* and *Psammocora plicata* (or similar facies). The lagoon face against the passage is similar to the seaward, but the terraced arrangement is less noticeable. The pinnacles are fewer and smaller, and the breadth is only about 30 yards. The drop outside is more abrupt, the reef ending in a cliff of 1½ to 3 fathoms against the passage. The surface is smooth, but various larger foliaceous and calcareous algae (*Halimeda*, etc.) flourish; neither nullipores, nor corals are found even at the extreme edge. Round the end of the point the conditions of the two sides merge into one another, but the terraces are broader; the outer is not marked with pinnacles, and slopes gradually to the depths below.

A series of large table-topped dead rocks are seen on the backwash of the breakers outside the cliff against the lagoon passage; they extend up from the level of the central conglomerate masses in a line to the point of the reef. Owing to the heavy seas I never succeeded in making good my footing on any of these, but they appeared to be pitted and bare of all organic growth except a few, low, green algae. They are apparently being eroded underneath, subsequently to topple over and to be completely removed in a similar manner to the conglomerate masses of the shore. I cannot find any record of such bare masses in the numerous accounts of coral reefs. In those, which I have seen, I can only compare them to the table-topped, raised reefs in some of the Lau islands of the Fijies; the erosion of the latter, however, is mainly between tidal limits. They may be the tables of much taller mushrooms, the stalks of which have given way, while the tables have not yet been cut down by the sea to the regular level in this position. *I am, however, rather inclined to believe that they are due to a broadening of the passage, and that they show the maximum effects which can be produced by the combined current and breaker actions on the reef.* A reef-flat consists of buttresses and masses which by organic growth have become joined together. The water has got behind some of these, and the present table-shape results. The force of the waves would cause a rapid denudation of the consolidating sand, and the constant change of the water, due to the currents of the passage, an equally quick solution. The out-rushing water, carrying a large amount of dirt of all sorts in suspension, would prevent any organic growth, so that the former actions would be unimpeded.

Between Kodi and Mou-Rambu points the reef is very similar to that eastwards of the former. There is a steep, boulder-strewn beach, and below this a series of terraces—usually three with a step of 1 foot to each—before the regular outward slope commences. The pinnacles of conglomerate are sparser, but usually a well-defined row marks the outer limit of all except the most seaward, which is never uncovered at any tide. The latter terrace is not well defined, being a flat for a certain distance and then tailing off seaward into the outer slope. Its inner part is completely covered with low, green algae, which to seaward give place to large nullipore areas with occasional colonies of *Madrepora*, *Pocillopora*, *Coeloria* and *Psammocora* in the hollows. The inner terraces are to some extent covered with green algae, but neither nullipores nor corals are found except very rarely in

shallow pits. *Often bare patches of rock occur, the pinnacles are constantly falling, and there is no doubt but that they are being rapidly eroded to the level of the outer terrace.*

Off Mou-Rambu there are four terraces, the most seaward with the same characters as the outer of those described above, but about 35 yards in breadth. The second has only a very few pinnacles, mostly at the outer edge. The third is studded with blocks, the outer limit being marked by an almost complete line, and the fourth, or innermost, is a rocky mass of conglomerate with top awash at ordinary high tide, broken up by a number of fissures, through which the water escapes after each successive wave.

In Ko-Vari bay the inner terrace forms a ridge at the base of the beach, 3½ feet above the low-tide limit. It is quite smooth, and formed of a conglomerate of sand and coral fragments. Parts consist of the ordinary coral conglomerate, but most is of beach formation (see page 37). It is being worn away on the surface, eroded underneath, and great slabs are constantly being broken off, the action nevertheless being much slower than on the coral-rock. The reef outside this inner terrace varies in breadth to 45 yards. Two terraces, each 10 to 12 yards across, occur, the inner smooth and bare of organic growth with a well-marked line of pinnacles on its outer edge, the seaward 1 foot lower, somewhat hollowed out in the centre, edge marked only by an occasional pinnacle and the surface covered with green algal growths with nullipores to seaward. An outer flat starts 1 foot lower; it varies up to 25 yards in breadth, and slopes gradually to a depth of about 5 feet, where it gives place to a succession of coral and nullipore masses. Its surface is covered with green algae, nullipores and corals of the usual genera in addition to massive and branching facies of *Porites*.

From Ko-Vari bay westwards the terrace formation disappears, giving place to a broad reef-flat. Masses of conglomerate, however, crop out at the base of the beach right round to the end of the island. Off Teveratu point the beach is very steep,—being formed of large boulders from the conglomerate,—and merges below into the reef, which is about 80 yards across. Three parts may be readily distinguished; an inner 20 yards broad, bare with a few rock masses, the remains of the terrace formation; a middle part, 40 yards across, never completely uncovered at low tide, the typical reef-flat; and an outer part, which slopes for about 1 foot in a breadth of 20 yards, consisting of great buttresses, perhaps divided across, the fissure zone. The reef-flat is noticeable in this position for the remarkable abundance and luxuriance of coral growth, as compared with the same part to the south and west of the atoll, and generally with the Maldivan reefs. Three or four facies[1] of *Madrepora* abound, with low branches and spreading masses, in places covering over 20 per cent. of the surface. Other corals spread over an additional 20 per cent., *Coeloria daedalea*, *Pocillopora coespitosa*, *Leptoria tenuis*, *Orbicella* (two or three species), *Pavonia repens*. *Psammocora plicata* and *Porites palmata* being the most numerous[2]. The fissure zone is simply a part

[1] By the term facies I imply simply a mode of growth. I cannot use the term species in referring to *Madrepora*; it is too precise, as I am uncertain whether all, while appearing distinct, are not really the same species. The determinations of the species, while usually accurate, are only intended to convey an idea of the facies of the genera represented. More massive species of *Pocillopora* and *Porites* were also obtained in addition to specimens of *Prionastraea*, *Hydnophora*, *Goniastraea* and *Astraea*.

[2] I am at a loss for a complete explanation of this great luxuriance of coral growth, unparalleled in my experience of similar reef-flats, both for quantity of coral and variety of genera and species. Teveratu point projects to the south-east, eight points from either of the prevailing winds, the

of the reef-flat, which is broken into buttresses and masses by the channels along which the superincumbent water escapes. The fissures vary enormously, some being only a few inches across, others many yards, serving perhaps as boat-channels, the waves surging through and not piling up as breakers. The channels gradually slope from the reef to a depth of about 2½ fathoms at the ends of the buttresses. The latter may be of almost any size, and are often much intersected. The rollers break just outside their seaward ends, which in any one position lie approximately in line with one another. Off Teveratu the buttresses are smooth on the top, covered with seaweeds, with all the species of corals of the true reef-flat, together with many stunted colonies of some massive facies of *Pocillopora*. To seaward they end more or less precipitously, but towards the fissures often overhang from 1 to 2 feet; their edges and sides—except where they are overhung—are completely covered with encrusting nullipores. Some of the channels extend right into the true flat, but none are large enough for boats. They have no coral growth, but boulders of recent coral origin may lie in them, generally more or less bedded in sand, perhaps being consolidated to the rock by nullipores.

The reef off the lighthouse and the western parts of the island exhibits the same divisions as at Teveratu, but the true reef-flat is about twice as broad. The beach is formed of small boulders and sand, tailing off into a rough area, 20 yards broad, which represents the inner zone of Teveratu. It has the same characters as the latter but less intensified, and further is strewn with coral masses, some thrown up by the waves, but the majority washed down from the land behind. I could find no trace of any consolidation going on at the present day, the loose masses usually lying bedded in a little sand, which may have a few crustaceans and worms, perhaps also a holothurian or two and some actinians. The under sides of the blocks, where exposed freely to the water, are bare, or covered in patches with thin sponge and Tunicate colonies. The broad flat is almost devoid of life of any sort; its surface has a somewhat slimy appearance from the mud and dirt. Such algae as grow on it are small and filamentous, silted at their roots with mud. A few small. pits are found, having perchance a boulder or two bedded in sand, the whole of the rest of the hollow obliterated by Halimeda, or some similar alga with calcareous leaves. The fissure zone is the same breadth as off Teveratu, but it is higher, and resembles more the same zone, described by me at Funafuti and Rotuma[1]. Its surface is pitted, and almost completely covered with low green algae and nullipores. In larger pits corals may grow, but the colonies are of small size[2], a species resembling *Pocillopora coespitosa* being the most common; an incrusting *Montipora* alone attains any magnitude, although most of the genera found at Teveratu may be represented. The seaward edge of the zone forms

ordinary currents caused by which would be bound to sweep round it. Probably the seas always break on it heavily, keeping the water of the reef-flat cool, and practically at the lowest tides preventing any drying up of the coral polyps. The whole reef, too, having a rocky shore, is singularly free from mud and dirt of all sorts. On the whole I am inclined to think that this luxuriance only dates back for two or three seasons, which have been peculiarly favourable. The small size of most of the coral growths lends this view some support.

[1] "The Coral Reefs of Funafuti, Rotuma and Fiji, etc." *Proc. Camb. Phil. Soc.*, vol. IX., pp. 417–503. (1898.)

[2] This is a most remarkable feature along the whole reef in this position, few of the colonies being more than a few inches across. At the commencement of the much delayed south-west monsoon in August, 1899, the beach was strewn with small coral fragments, and there seemed to be considerable death among the reef corals, owing to dirt and mud. I am inclined to think that most of the branching coral colonies had been formed since the last south-west monsoon (in this case 10 months), and that few or none survive it.

a marked line, and the fissures are small, many closed over by nullipores, which may perhaps leave small blowholes.

The reef between the last two positions described gradually varies from the one to the other. In one place for about 200 yards the whole of the seaward face of the buttresses and for some distance up the channels is singular in being absolutely covered over by a yellow zoanthid actinian. Off Wiringili and Ragandi islands the reef is nearly the same as off Teveratu point, but the conglomerate zone is broader, more marked, and very rugged (Fig. 10). Between Wiringili and Minikoi the reef outside the boulder zone is

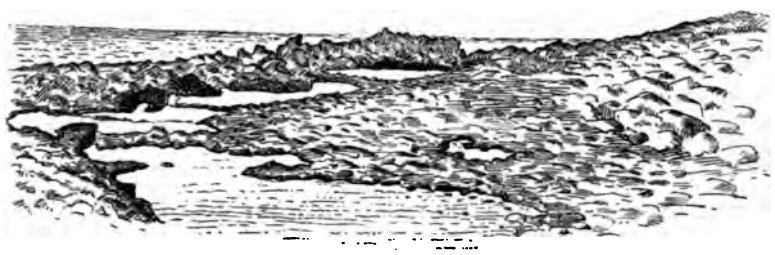

Fig. 10. Seaward beach of Wiringili with masses of conglomerate. (*From a photograph.*)

intermediate between the reef off the end of the large island and the reef of the whole of the west and north sides of the atoll. The latter does not differ materially in different parts, and the description in one position will serve for the whole.

In a cross section between Wiringili and Ragandi three zones are well defined, the fissure, reef-flat, and boulder. The fissure zone does not very materially differ from that off the end of Minikoi island, but its edge against the sea is more irregular, some masses dropping with a cliff to two or three fathoms, others tailing off gradually. It varies in breadth up to 30 yards, and slopes about two feet in this distance from its crest; the latter is a slightly higher part just exposed at low springs, six or eight yards across. Further outside the slope quickly attains a depth of four or five fathoms, slowly increasing for some distance. The bottom is fairly smooth, covered with spreading nullipores and studded with round masses of the same and coral colonies, the former always with a coral core. There is no appearance of the great masses found off the reef to the south of Minikoi island. The seas break just outside the edge of the zone, which except the crest is swept by the waves in all weather. The fissures seldom have overhanging sides, or any accumulation of coral blocks or sand in their channels. They generally start in the crest and slope to about 2½ fathoms outside; few reach through to the reef-flat, from which at low tide the water cannot readily escape seaward. The water at low tide rushes up the fissures and a certain amount wells over on to the reef-flat, though most, being thrown back by the crest, escapes with great force down the channels. The buttresses are pitted on the surface into small rounded hollows, which are often filled with algae, allied to *Halimeda*, or with small coral colonies, mostly branching facies of the usual genera. Generally, however, the hollows are empty, the rock beneath merely covered with a nullipore, or a flat green alga of some sort. If the surface be broken, a nucleus, usually of coral, is reached after several inches of a light concretion of worm tubes and *Lithothamnion*. The walls and floors of the

fissures are usually smooth, and encrusted completely with nullipores. Free animal life of any sort is rare; a few thick-spined Echinoids and large crabs wedge themselves into the hollows; brilliantly coloured fish wash to and fro with the waves in the fissures; between the branches of corals and weed a few Alphaeids find a refuge with an occasional Cyprid and Stromb. The crest of the zone is not always present in such a marked manner, though an inner part, densely covered with green algae, in which the fissures mostly end, can always be distinguished. Its surface has the regular worm tube and nullipore structure, only in greater thickness; corals are rare, a few mammillated nullipores being the only calcareous organisms.

The reef-flat is about 50 yards in breadth, presenting almost the same characters as in the last position described. The greater part of its surface, being situated about 6 inches below the crest of the outer zone, is at any state of the tide covered with water, in which there must be some change through the fissures. Its surface is absolutely free from loose coral boulders, and is for the greater part bare save for low algal growths. It is clean, with no dirty appearance from mud or sand, and, if broken into, is seen to be formed of hard coral rock. Small incrustations of nullipores are found, but they are never of any real importance, nor can they in any way affect the general height of the whole. The same genera of corals grow as are found on the fissure zone; spreading forms of *Montipora* alone attain any size, their colonies sometimes covering 2 or 3 square yards. The most abundant genus is *Pocillopora*, of which two forms, finely and coarsely branching, are numerous; *Coeloria daedulea* also is of considerable importance. Corals attract the eye, and hence tend to assume an undue signification. It is very unusual for them to cover more than 10 per cent. of the surface of any reef, sufficient for wastage, but not enough to alter the general level. Towards the exterior masses of hard rock, 2 to 3 feet high, are found irregularly about every 40 yards. They are pitted on the surface and rotten, perhaps the outside a mass of worm tubes, surrounding a solid rock core. Although I passed along this reef in the beginning of September, 1899, after very heavy south-west gales, I failed to find any large masses thrown up by the seas (negro-heads), nor did I ever find any rocks on the flat in process of cementation on to the reef. Blocks added thus usually can be easily split off with chisels along the line of cementation, but I failed to break any of these. *I am hence driven to the conclusion that these masses are true pinnacles, that they once absolutely were part of the reef itself and were left, while the rest was completely washed away.* Of free animal life, other than that found on the fissure zone, Holothurians alone are prominent.

Of these two zones as far as the north passage into the atoll little further need be said. They have nearly the same characteristics, but the fissure zone increasingly becomes more broken and less defined at its outer edge, which tails off very generally by similar masses to the seaward depths. The crest is in many parts absent, and the two zones merge into one another; pinnacles are scarcer. In three places between Ragandi and the passage the reef is lower, forming boat channels, which are used above half-tide in the north-east monsoon. These passages are merely extra large fissures, which run further into the reef-flat; they are kept open mainly by the scour of the tide, preventing coral and other calcareous growths.

The boulder zone (Fig. 11) is an area of rough blocks of rock, separating the reef-flat from the lagoon. It is about 30 yards broad, moderately sharply defined on both sides;

some of its masses attain a height of 3 feet above the reef-flat, but the general level is 1 to 2 feet less. What appears to be the inner part of the reef-flat forms the foundation; it is to some extent worn into holes, in which the larger loose masses lie, imbedded in sand. The three islands merge at their ends into this zone, masses of the conglomerate extending out from each for 100 yards or more along it. It has a twofold origin, consisting of boulders cast into this position from the reef and lagoon, and also of masses of the conglomerate, some loose and some attached to the solid platform below. Relatively little of the whole, however, consists of masses attached to the reef, the greater part being formed of loose blocks of the old coral-rock. Towards the outer side a certain number of coral blocks are thrown up from seaward, and on the lagoon side also a few may be washed

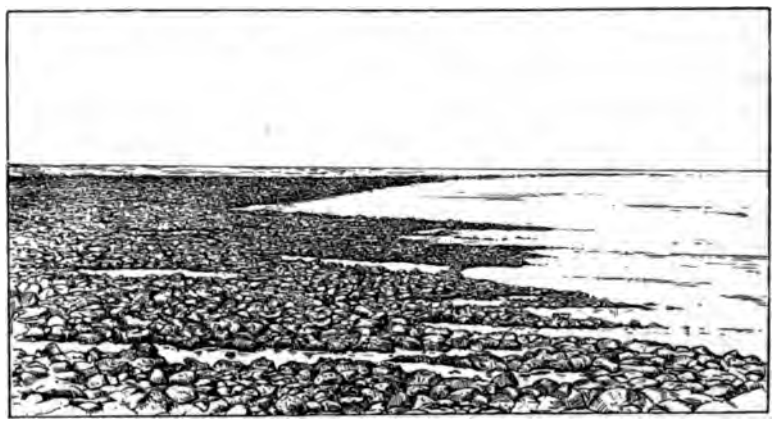

FIG. 11. Boulder zone and reef-flat between Wiringili and Ragandi. (*From a photograph.*)

up. The sand beneath is coarse, consisting of fragments of the conglomerate and the washings of the reef. The boulders are singularly free from all boring and other destructive organisms; their exposed surfaces are absolutely bare of any animal or plant life. Little can grow on the basal reef on account of the sand, and indeed no fixed organisms of any sort are found save on the undersides of boulders, which may be almost covered with thin sponge, Tunicate or Polyzoa colonies in numerous small incrustations with possibly a little Hydroid and Actinian growth as well. Brilliantly coloured Turbellaria and similar looking Nudibranchiata browse on these. Crabs of thin compressed genera and Ophiurids hurry to escape on every side; numerous Macrurans dart for shelter. Under the boulders a few sharp-spined Echinids, thin-skinned Holothurians and large Cyprids lie free on the surface, and in the sand may be found an occasional Polychaet and Sipunculid. In places the boulder zone may be lower, where the water of the rising tide finds its earliest access to the lagoon, and its surface practically smooth and bare.

While the boulder zone has the above enumerated characters as far as Ragandi, it ceases further north to be nearly so well defined. Indeed it is merely the inner part of the reef-flat, sparsely strewn with boulders with a few masses of the conglomerate here and there. The latter do not exist opposite the boat channels, and are most numerous intermediate to these. Close to the north passage there are a large series of such masses, many of great size, forming almost a bare conglomerate flat, covered with about a foot of water at high tide.

SECTION 4. THE LAGOON.

The distribution of the fauna in the lagoon of an atoll is dependent on the currents, which bring food and water to the various organisms. To ascertain their force and character I anchored for five nights in different situations, taking serial observations on the directions and rates of the current, temperature and surface fauna[1]. For rate of current I used Messrs Negretti and Zambra's current meter[2].

To summarise my observations, the tide sets in mainly over the south and west reefs of the atoll, carrying with it weed and dirt from the reefs together with a certain amount of plankton, but in any situation relatively little as compared to the quantity which enters by the north passage. At first the tidal effects were felt in the latter channel, but about half-tide, when the boulder zone began to be covered, a reversal of this current was experienced; a previous current inwards of 1 to 1½ knots gave place an hour before high tide to an outward current of ½ knot, increasing to 1 knot at high tide. With the ebb a slight inward set over the reef still continued, and was felt until the boulder zone began to be uncovered. The current in the north passage increased up to 4 knots at a depth of 1 fathom, the surface nets catching a mixture mainly of weed and mud with some few Crustacean larvae. Away from the immediate neighbourhood of reefs I never recorded a current in the lagoon of more than 1 knot, but incidentally I proved that the water is to some extent changed by admixture in every part except perhaps immediately opposite the lighthouse. The advent of the water from without was shown by a slight change (lowering) in the temperature and the specific gravity of the lagoon-water, and in the arrival of the true sea-plankton. The latter was mainly noticeable in its Medusae, Diphyids and Sagittae; Appendicularia and Salps were also found. Crustacean constituents were not relatively numerous. Minikoi is a small atoll with a relatively very large reef surface as compared with the lagoon. The fact that there should be a thorough circulation of water is hence of great importance and perhaps accounts for the richness (in quantity, not in species) of the fauna, which the lagoon contains[3].

The shore of Minikoi as far north as the village slopes gradually into a broad sand-flat, but beyond this a level reef commences and continues up to the north point. This reef varies up to 300 yards in breadth, and no part of it is exposed even at low-tide springs. It slopes absolutely from the base of the beach, and has about 3 feet of water at its edge, where it drops steeply into 2 fathoms of water. Masses of conglomerate, such as are found in the beach, may occur on its surface for some distance, gradually further out decreasing in size. At Boni-Kodi the reef is 216 yards broad from the base of the beach, and pinnacles extend 170 yards out. Its appearance in this position bears a close comparison with the reef outside the island, in that it is very obviously a solid

[1] The situations were opposite points, where the reef is low near Wiringili and Ragandi Islands, opposite the channel of Neru-Magu, the centre of the lagoon, and just inside the north passage. The last was not very satisfactory, as the night was stormy, and my boat was twice filled with water by breaking seas.

[2] *Vide* p. 22. For slow currents, such as I wished to record, a lighter and larger form of instrument is desirable. The screw should have three or four blades, and great attention should be paid to its bearings to avoid friction of every sort.

[3] My observations were made in the south-west monsoon. From general considerations I cannot see why there should not be nearly as good a circulation of water in the north-east. The main island would be a barrier to some extent, but the currents in the north passage would be probably profoundly modified and stronger inwards, changes which could not fail to be advantageous.

mass of rock and not a sand formation. Its surface is muddy, slimy and worn into holes more or less filled with sand; it is bare and smooth for the greater part, and boulders are practically non-existent. The whole area is singularly devoid of animal or plant life, sessile or free. A few species of coral grow at the very edge, but on the surface I only found a few small colonies of *Porites arenosa*; delicately branching nullipores may exist and also *Halimeda*, but weed is generally scarce.

The sand-flat at the south of the main island extends up round the reef to the west and north, covering about half the total area of the lagoon. The whole, except a small part near the lighthouse, is completely covered even at low-tide springs, the greater part having 2 to 3 feet of water. Around the sand-flat, wherever the reef exists, an outer zone, 100 to 150 yards broad, may be separated, characterised by its abundant growth of corals, the rest of the sand being absolutely bare. The slope from the reef to the general level of the flat occurs entirely in this area. The principal coral is a species of *Madrepora* with massive branches, which is everywhere abundant in this situation. Other more delicate Madrepores occur as well, mostly in isolated colonies, but a stag-horn species with branches up to 1 inch in diameter forms in places close to the boulder zone regular groves. *Porites arenosa* is found everywhere, in masses up to 20 feet across, dead in the centre, but living at the edge, and places where the currents are not greatly felt are often almost completely covered by it; the masses are always free, their stalks having been destroyed, and are very generally somewhat hollowed out in the centre. *Pavonia repens* crops up anywhere, while the species of *Pocillopora*, of which there appear to be several, are found only opposite breaks in the boulder zone. Locally extremely common, especially near the western and northern reefs, are great masses of *Millepora*, *Heliopora* and *Psammocora*, while colonies of *Goniastraea*, *Astraea*, *Orbicella*, *Prionastraea*, *Siderastraea*, *Mussa* and *Euphyllia* are often met with, frequently growing in the hollow masses of *Porites arenosa*. On the under-surfaces of any of the above *Agaricia* may grow, and various species of *Fungia* are very abundant on the bare sand. *Halimeda* abounds, growing among the basal branches of *Madrepora*, but other algae can scarcely be said to occur. A mere glance at the above list of the more important genera serves to show the richness of the area, and the bold growth of the colonies themselves proves that the position on the whole is one eminently favourable to them. The parts poorest in corals lie immediately behind the boulder zone, where it is especially high or low, the stillness of the water and the too rapid currents both being unfavourable. Surveyed from a boat at high tide the presence of breaks in the boulder zone can be assuredly told by the white, sandy bottom continuing up to it. Over the richer areas at the sides of these, heavy boots and putties are required, as one literally breaks one's way through groves of coral. The skeletons of living corals (*i.e.* covered by the living polyps) from the area are singularly free from destructive organisms of all sorts, no Polychaets nor Sipunculids; even sponges, which pervade the hard parts of most or all reef corals, do not exercise much sway. The growth is hence probably extremely rapid, and yet the decay must be as quick. The area is certainly not increasing in height. Dead corals are found bored through and through; they soon rot away, and break down into sand, or are dissolved.

The reef of the boulder zone can at its edge be very distinctly traced under the sand, which varies between that of the former zone and the fine mud of the centre of the atoll.

Indeed with a short crowbar the presence of such a reef is indicated often for 30 to 40 yards, and it would appear to underlie a not inconsiderable part of the sand-flat. Attached organisms, other than those which have been already mentioned, are rare in this outer area, but nearly all the free forms of the boulder zone with the exception of Ophiurids are found in as great, or even greater abundance. The black beche-de-mer is extremely numerous, and myriads of small fish dart between the branches of the corals. Annelids and Sipunculids are rare, but generally free life on the coral reefs of the deep sea is nowhere as abundant nor varied as on tropical continental coasts, or on even moderately rich ground of the Mediterranean and English seas.

The rest of the sand-flat is nearly bare of all organic growth. Opposite Minikoi island two small green algae are found in patches, and here and there clumps of a finely branching nullipore grow, nearly imbedded in sand. Surface-living Holothurians are very common in places, and a small species of *Ptychodera* occurs locally under the weed in great abundance. Living in the sand are large numbers of a white Holothurian, a large Sipunculid and two *Synapta*, besides vast numbers of smaller species of the same groups. In addition heaps of sand, 4 to 5 inches high, in a calm sea stud the whole, the castings of an immense Enteropneust, the end of the body of which is often 1½ inches in diameter when distended with sand.

The sand ends about 100 yards outside the line, marked 2 fathoms in the chart, opposite and to the north of Minikoi island, the intermediate area generally being covered with coral shoals, intersected by channels with about 2 fathoms of water. These shoals are usually flat on the top, bare or hollowed out in the centre, with perpendicular, or overhanging sides—especially towards the deeper part of the lagoon—covered with coral growth. On their summits the chief coral is *Porites arenosa*, but all the previously mentioned lagoon genera are represented; massive Astraeids tend to be the dominant forms on the sides. All are much infested with boring organisms, *Lithodomus*, Cirripedes and a Gastropod as well as the usual Sipunculids and Polychaets. The patches decrease in size towards the sand area, on which they seem on the whole to be encroaching. To the south-west and north of the atoll coral patches may occur near the edge of the sand-flat, but there is no definite broad line. This is especially the case by the boat channels and northern passage. By the side of the latter I found what appeared to be the remains of a patch, which for some cause or other had been killed the previous year. It was a round mass, standing in 3 fathoms with 1 foot of water covering it at low tide, sides precipitous, diameter about 18 yards. Its surface was rotten, its sides extremely sparsely covered with living corals—the greater part dead at the base—with much dead and rotting coral. Four other patches seemed to be in the same condition, but they had a certain amount of weed, and would appear to have been killed some time previously. Several other reefs in the vicinity had also been affected, but none to the same extent; some, however, had had in places quite sensible slips at the sides. Free animal life on all the shoals, it may be noted, is extremely scarce.

The slope from 2 or 2½ fathoms, the general depth of the edge of the surrounding flat and reef, to the deepest waters of the lagoon is gradual and regular. Coral patches occur everywhere but much more sparingly in the deeper waters and towards the north; indeed the centre of the lagoon is fairly clear. The patches all reach within a couple of feet of the surface. With the lead I failed to find any incipient patches, and I lined

the whole lagoon with dredgings without finding any trace of such. In its southern half this deeper area is covered with extremely fine sand with delicate shells and Halimeda leaflets. This gradually gives place northwards to an area of broken coral fragments in process of decay, studded perhaps with small colonies of Polyzoa. Towards the passage *Polytrema* and nullipores begin to appear, and the bottom consists largely of their rounded masses, 1 or 2 inches in diameter, each on a coral core. The depths in the Admiralty Chart are to all intents accurate, but the 2 fathom area is greater, as also is the 5 fathom. The latter indeed occupies the whole centre, and in the middle of it is an elongated pit with 7 to 9 fathoms. Dredging in this part of the lagoon is extremely unproductive. No fixed organisms other than those already mentioned were obtained. For the rest 2 Gastropods, 1 Lamellibranch, an Asymmetron, a Carib and a few sand-loving Macrura alone were obtained in any considerable numbers.

Section 5. The History of Minikoi as an Atoll.

In the foregoing I have been at some pains to show that an elevation of at least 24 feet must be allowed for the whole atoll. I do not myself consider that the change of level has been much greater than this. Therein I am supported by the general appearance of the corals in the conglomerate, which indicates a formation in shallow water. The point may seem a small one, but it gains in importance from the wide distribution of absolutely similar conglomerate on the atolls both of the Indian and Pacific Oceans. Yet I cannot maintain that an ocean reef at a depth of 10 or even 15 fathoms, swept, as is probable, by a strong current, would not if elevated to the same height have in its conglomerate a similar structure. The sea has now been quite sufficiently explored in the tropics to show that relatively few reefs exist of such a character, most having at least grown into true atoll reefs awash. The reef, too, would have had to have been caught by the elevation at just the right period, for with pure oceanic conditions—the most favourable, if judgement may be based on the more perfect forms of atolls, afar from land,—it could only take a relatively very short time for the reef to rise from 10, or even 20 or 30 fathoms to the surface. The rocky area of the land lies obviously on reef. Remembering both this fact and the regularity of the existing reef, I may point out that such deep shoals have not usually perfect rims, but merely here and there peaks and banks approaching the surface.

It appears to me then a fair assumption that the atoll existed as such when the change of level took place. In further support of my contention that the elevation has been but small, I would point out that the conglomerate appears to have been of very recent formation, a character fully supported by the same rock in the whole of the Maldive Archipelago. Coral-rock, when elevated in any great thickness, soon loses its distinct, organic structure, assuming a hard, uniform, crystalline character by rain-water solution and the reprecipitation of its line. This may be seen in the Fijies, Tonga, Pelews, Solomons, Christmas island and West Indies, indeed wherever reefs of any considerable thickness have been elevated above the waves. The island of Viti Levu, Fiji, is perhaps an exception, but the conditions are peculiar here, in that there must have been several elevations and subsidences, in which the coral-rock was covered with the practically impervious so-called "soapstone[1]." Of course the argument depends on the assumption with which I started,

[1] *Vide Proc. Camb. Phil. Soc.*, vol. IX., p. 453. (1898.)

but with each additional inch eroded the condition of the rock should differ further from that of the modern reef, while there is actually little or no change.

It remains then to consider the form of the atoll, when first elevated, as far as may be deduced from the evidence before us. I have already pointed out that gain and loss are both taking place in respect to the land, and the distribution of these two factors. *First it is obvious that the atoll has been stationary for a considerable period of time* on account of the broad reef-flat round most of its circumference, together with the lagoon-reef off Minikoi island and the broad sand-flat everywhere. Further there are the same actions of gain and loss in respect to the reef. Without entering into detail no one doubts, so far as I am aware, that a reef in a stationary area, exposed to the sea, would gradually grow seawards. The buttressed edge of the reef of our atoll, all covered with calcareous organisms, the masses growing on to it, and the further masses seaward, covered with nullipores and corals, give indubitable presumption of gain from the sea. *On general grounds and from experience I consider that the sea gains on the reef in lagoons, where the circulation of water is considerable.* Specifically I may at Minikoi point to the dead reefs near the north passage, and to the similar character of the whole surface and edge of the reef, extending along from the village to the north point[1].

Seeing the changes taking place I summoned all the old men of Minikoi to my aid, and by their assistance I am enabled to reconstruct to some extent the appearance of the atoll at the commencement of the last century. First there has been little apparent change, either in the seaward part of the reef, or in the outer beach, save only that the outer paved path was at that time perfect from the village northwards and separated by shrubs from the sea. The rocks at Kodi point further were crowned with coconut trees, and joined to the main island. Belts of coconut trees existed right up from the village to the north of the island along the lagoon shore, while now only a few are found at Boni-Kodi. Indeed the natives add an average breadth from memory (60 years) of 30 to 40 yards, an amount which seems incredible in a closed lagoon, but is fully supported by the strewn coconut and other trees on this beach as well as the house remains at Bali-mi-Hungi. The action continually goes on, but hurricanes are especially destructive, causing slips everywhere along both lagoon and outer beaches. Against this must be recorded an extensive gain—60 to 70 yards it is stated—between the village and Moli-Mati point, but Tundu point has retreated almost a like distance, the intermediate area varying. An island, Tori-Gandu, on the reef to the west of the north passage existed with 4 or 5 coconut trees, while Ragandi at the same time had as many as Wiringili now, *i.e.* about 30, but the latter island is only slightly smaller. Lastly it was stated that the north passage has broadened greatly, but views as to its deepening, though held by the majority, produced an acrimonious discussion, from which and on other grounds I am not inclined to credit any considerable difference.

The presence of conglomerate masses I can only regard as indicating the existence of former land in any position, where they now occur. The land then must have at one

[1] My soundings, as compared with the chart, gave evidence of such inconsiderable change in the same direction that I do not care to lay any emphasis on them. A small miscalculation in the state of the tide, or in the positions of the various points taken for fixation, might explain the differences of the two sets of soundings.

time extended round the whole atoll with only a single break perhaps to the north with lower parts here and there, where boat channels across the reef now exist. The seaward shore must at that time have been relatively steep, like that between Kodi and Mou-Rambu points at the present day but without terraces. The old reef must have had extensive sand-flats, extending out from it into the lagoon on every side, and the lagoon on change of level, if it existed at all, must have been at most a mere small, central pool with a slight ebb and flow of the tide through a single inconsiderable channel to the north. Indeed save for this small channel Minikoi cannot at one time have been far different from the low coral islands such as Oaitupu (Ellice Group), Mulaku (Maldives) and Tromelin, which exist in considerable numbers in both the Pacific and Indian Oceans. Supposing the land in the present atoll to be entirely swept away, the condition at the present day cannot be far different from that of the atoll before the change of level, allowing for its then smaller size.

(*To be continued.*)

HYMENOPTERA.

By P. CAMERON.

The Hymenoptera taken by Mr Stanley Gardiner in the Maldives and in the Minikoi Atoll number 25, of which two are parasitic (*Ichneumonidae*), the others belonging to the Aculeate section of the order. The number of species captured on the Maldives is 20; in Minikoi 10; 5 species are common to both groups. The known species are Indian forms of wide distribution in the Oriental Zoological region; and some of them, *e.g. Ceratina viridissima, Xylocopa aestuans, Polistes stigma,* and *P. hebraeus,* extend also into Africa and the Malay Archipelago. All the species, new and old, belong to genera of universal distribution in temperate and tropical countries. The genus *Megachile,* for example, ranges from the boreal districts of Europe and America to Australia, and few of the Pacific Islands are without a representative of it.

The Minikoi species were captured from June to September during the south-west monsoon, which is usually the wet monsoon; but in 1899 during the period of Mr Gardiner's visit the weather was abnormally dry, the rain not commencing until the second week in August. The Maldive species were taken in November and December, which were very dry months; but in October heavy rain fell. Hulule Island was visited in January and February, 1900.

HYMENOPTERA PARASITICA.

Fam. **Ichneumonidae.**

1. *Zanthopimpla appendiculata,* sp. nov.

Long. 11; terebra 4 mm.

A species closely allied to the doubtful *Z. punctata* Fab.; and which is certainly different from *Z. punctata* Krieger.

Hab. Minikoi, Laccadives.

Scape of antennae pale yellow; the flagellum brownish. Head yellow, except the ocellar region, where there is a mark longer than broad, which extends to the end of the vertex and is rounded in front. The face is strongly and closely, the clypeus less strongly, punctured. The head is not much developed behind the eyes, and is roundly, obliquely narrowed there. On the base of the mesonotum are three black marks touching each other;

the central is about as wide as long, transverse at the base and apex, and with the sides bulging out roundly; the lateral marks are larger; their base is straight and slightly oblique; their outer side is rounded outwardly; on the inner they are obliquely narrowed. On the base of the median segment are two black, ovoid marks, placed transversely, the broad end on the outer side; the basal area is wider than long; it becomes gradually, but not greatly, widened towards the apex, which is transverse; the outer basal areae are wider than long; the area next to it, in front, is triangular, oblique, and longer than the width of the base, where the bounding keel bulges out. Pleurae smooth and shining. Wings clear hyaline; the nervures and stigma are black; the areolet is distinctly appendiculated. Legs coloured like the body; the hinder tibiae are black at the base. On the abdomen are twelve black marks; the pair on the petiole are broader than long, and have a short, sharp projection on the inner side at the base; the second pair are small; the third are the largest; are about as wide as long and rounded on the inner side; the fourth pair are smaller and somewhat similar in shape; the fifth distinctly wider than long; the sixth are still wider, but not so long; there are no marks on the sixth and apical segments. In the ♀ there are no marks on the second segment; that on the fourth is very small; in the middle of the last segment are two curved oblique furrows.

2. *Enicospilus reticulatus*, sp. nov.

Luteo; abdominis apice nigro; metanoto reticulato; alis hyalinis, stigmate fusco. ♀.

Long. 14 mm.

Hab. Hulule, Male Atoll, Maldives.

Antennae luteous, darker towards the apex. The sides of the face and the clypeus have a yellowish tinge. The face is finely wrinkled in the middle and punctured on either side; the clypeus is smooth and indistinctly punctured at the base; the labrum wants the yellow tint of the clypeus; the vertex and the eye orbits have a distinct yellowish tint. Mandibular teeth black. Mesonotum fuscous, except at the base and sides. The scutellar keels are stout; the apex is closely, longitudinally striated. The base of the median segment is smooth, with the sides irregularly striated; the rest of it is irregularly, distinctly reticulated; on the apex the reticulations are oblique and less distinct in the middle below. Pro- and meso-pleurae closely punctured, the middle of the pro- and the lower part of the meso- closely striated. The metapleurae above shagreened; the lower apical part bears some striae. Wings clear hyaline; the stigma and nervures fuscous; the basal abscissa of the cubitus is thickened, the basal two-thirds being thicker than the apical part; there are two distinct horny points; the lower one is dilated and rounded behind; its upper part forms a somewhat triangular shape; the apical point is somewhat oval in shape. Legs coloured like the body; the hinder tarsi are shortly but distinctly longer than the tibiae; the anterior twice their length.

The transverse median nervure is received shortly behind the transverse basal; the recurrent nervure is bullated on the top; the disco-cubital nervure more widely in front of it.

HYMENOPTERA ACULEATA.

Fossoria.

Fam. **Crabronidae.**

3. *Crabro idrieus*, sp. nov.

Niger, mandibulis, scapo antennarum, linea pronoti, basi scutelli, apice femorum, tibiis tarsisque flavis; alis hyalinis, stigmate fusco. ♀

Long. 7 mm.

Hab. Goidu, Goifurfehendu Atoll, Maldives.

The scape of the antennae bright yellow; the flagellum is black, fuscous towards the apex; it is covered with a white pile and is distinctly thickened towards the apex. Mandibles bright yellow; the teeth black, with a piceous band behind them. Front and vertex opaque, the front is strongly, but not very closely, punctured; the vertex is less strongly and not so closely punctured. The frontal depression, the face and the clypeus, are thickly covered with silvery pubescence; the face is distinctly keeled in the centre; at the apex this keel slightly projects and is smooth and shining.

Pro- and mesothorax opaque, the mesonotum and scutellum are sparsely punctured; the mesopleurae less distinctly punctured. Propleurae shining; on the basal half are three or four irregular keels; on the apex two longish oblique keels, with two shorter ones behind them. The middle of the metaplurae is depressed and is, especially in the middle, obliquely striated. The following are yellow: an interrupted line on the pronotum, the tubercles, the scutellar keels, two large marks, rounded behind on the base of the scutellum. Abdomen black, except for an oblique, yellow mark on the sides of the second and third segments. The petiole is as long as the second and third segments united; the base above is flat, shining, and furrowed in the middle at the base; this part becomes acutely narrowed at the apex.

The tubercles are fringed behind with white hair; the part behind them is keeled; from the top of this keel an oblique smooth furrow runs; the keel behind the middle is obscurely striated. The "enclosed space" on the base of the median segment is stoutly, obliquely striated; in the middle at the apex reticulated; the apical slope on either side of the furrow is transversely striated, the striae becoming weaker towards the apex; the four anterior tibiae are lined with black behind, the anterior in front.

Comes nearest to *Crabro orientalis* Cam.

4. *Crabro musaeus*, sp. nov.

Long. 9—10 mm. ♀

Hab. Mahlos Atoll, Maldives.

Similar in coloration to the preceding species, except that the third and fourth segments are lined with black laterally above and with a mark on the sides behind; it is easily known from it by being longer, by the "enclosed area" on the median segment not being stoutly striated, and by the upper abscissa of the transverse cubital nervure

being almost in a line with the lower, and of almost equal length to it: in *idrieus* the lower is longer than the upper, which is on a different angle with it, it being only slightly oblique.

The lower part of the head, inside and out, is thickly covered with silvery pubescence; the clypeus is stoutly keeled. The scape of the antennae, the mandibles, except at the apex, an interrupted line on the pronotum, the sides of the scutellum, the scutellar keels, the tubercles, a mark on the upper side of the mesopleurae, between the two furrows, a longish line on the sides of the third segment at the base, an oval mark on its sides at the apex, and a shorter line on the sides of the fourth segment at the base, yellow. The furrow bordering the scutellum is crenulated; the post-scutellum is closely, longitudinally striated. The area on the metanotum is furrowed down the middle and is finely and closely, obliquely striated. The propleurae bear curved, not very stout striae. The narrowed basal part of the petiole is shining and obscurely striated; the nodose (and larger) apical part is opaque. The stigma and alar nervures are fuscous; the apical abscissa of the radius has a sharp, straight, oblique slope. The four anterior femora are for the greater part, the hinder are entirely, black; the four front tibiae are yellow, lined with black behind; the posterior yellow, black at the base behind, the tarsi are yellow.

5. *Trypoxylon erythrozonatum*, sp. nov.

Nigrum, abdominis medio rufo; tarsis anterioribus albis; alis hyalinis; nervis stigmateque nigris. ♀.

Long: 15—16 mm.

Hab. Hulule, Male Atoll, Maldives.

Scape of antennae brownish beneath. Face, clypeus, and the lower part of the eye incision densely covered with silvery pubescence. Mandibles for the greater part ferruginous. The upper part of the front bears a narrow longitudinal keel; the lower is raised, the raised part becoming gradually wider towards the apex. Thorax thickly covered with rather longish white hair; the furrow below the tubercles is smooth; there is a shallow central furrow on the basal region of the median segment, which becomes gradually wider and deeper towards the apex; the apical furrow is wide: the sides have an oblique slope. Legs black; the basal two joints of the four anterior tarsi and the calcaria are white; there is a narrow pale band near the base of the hinder tibiae. The wings are slightly infuscated at the apex. The apex of the petiole and the second and third segments are rufous.

6. *Trypoxylon melanurum*, sp. nov.

Nigrum, tarsis, tegulisque fuscis, alis hyalinis, stigmate fusco. ♂.

Long: 10 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives; Minikoi, Laccadives.

Antennae black, fuscous towards the apex; the last joint is as long as the preceding three united; on the underside it is dilated at the base, narrowed towards the apex; the middle joints are slightly dilated beneath. Front and vertex closely punctured; on them is a large area; its upper part is rounded and encloses the lower ocellus; its lower is

more narrowed towards the apex; the part occupied by it is raised and reaches near to the antennae, where it is prolonged as a short, stout keel; from the junction of the two parts a curved keel runs to the eye incision. The lower part of the eye incision, the face and clypeus are covered with silvery pubescence. Pro- and mesothorax smooth and shining. The base of the median segment bears stout, longitudinal keels, the two central of which are more widely separated; the rest of the segment is stoutly, irregularly, transversely striated; the basal half has two longitudinal keels which form a central area, rounded at the apex; there are two longitudinal keels on the apical slope, which unite near the apex of the segment, this second area being more sharply pointed at the apex than the basal one. On the base of the mesopleurae is a wide, deep, crenulated furrow, bisected above by a smooth, curved one. Legs black, the tarsi testaceous, darker at the base. Wings hyaline, the nervures fuscous. Abdomen entirely black.

Fam. **Scoliidae.**

7. *Elis thoracica* Fab.

This family is represented only by the above, a common Eastern species. Its ♂ has not yet been described with any degree of certainty (cf. Saussure, *Catalogus Specierum generis Scolia*, p. 188, and Bingham, *Fauna of Brit. India, Hymen*, p. 99) but, in the collection, there are some males which can only be connected with *thoracica*. They are densely covered with longish cinereous pubescence: the sides of the clypeus broadly from top to bottom, the apex of the pronotum, the yellow extending laterally to near the tegulae, two broad marks on the base of the scutellum and a mark on the centre of the post-scutellum, yellow. The hair on the median segment is denser than on the rest of the thorax; the oblique furrow on the flat apical half of the mesopleurae is distinct. The wings are hyaline, violaceous in tint at the apex; the radial cellules smoky. Legs black; the apex of all the femora, the outer side of the tibiae and of the base of the front tarsi yellow. Abdomen violaceous-black; the basal three segments above have the apices broadly yellow; the black dorsal parts are dilated in the middle and laterally, the basal projections being narrowed at the apex; the fourth segment is more narrowly yellow at the apex; the black band there is also dilated, but only slightly in the middle.

Hab. Common in Minikoi, Laccadives; one ♂ from Goidu, Maldives.

Fam. **Sphegidae.**

8. *Sceliphron madraspatanum* Fab.

Hab. Goidu, Goifurfehendu Atoll, and Fainu, Mahlos Atoll, Maldives.

9. *Sceliphron violaceum* Fab.

Hab. Hulule, Male Atoll, and Mamaduwari, Mahlos Atoll, Maldives. Minikoi, Laccadives.

Both these species of *Sceliphron* are of universal distribution in the Oriental region.

10. *Bembex maldivensis*, sp. nov.

Long. 17 mm.

Hab. Goidu, Goifurfehendu Atoll, Hedufuri, Mahlos Atoll, and Hulule, Male Atoll, Maldives.

Belongs to Bingham's Section A, and comes near *orientalis* and *borreri*. ♀. Antennae entirely black. Head densely covered with long, white hair, the clypeus also with silvery pubescence, the edge of the pronotum narrowly, the labrum and the mandibles to the teeth, pale yellow. Thorax densely covered with silvery pubescence; the prothorax, except behind, two narrow lines on the centre of the mesonotum, two broader, shorter, almost united, transverse ones near the apex, the apex and sides of the scutellum, the apex of the post-scutellum; a broad curved line on the centre of the median segment; the sides broadly from near the middle, the base of the mesopleurae, the mark dilated at the top so as to enclose the tubercles, a large vertical mark in the centre, which becomes gradually wider from the top to the bottom, a smaller, more irregular mark on the apex behind, a crescent-shaped mark on the metapleurae behind the spiracles and the apex broadly—the mark below extending backwards beyond the middle—sulphur-yellow; legs yellow; all the coxae and trochanters; all the femora broadly in front and behind; a line on the fore tibiae behind and a shorter one in front, black; the spines on the fore tarsi are long, stout, and, except the basal one, black. The basal joint of the fore tarsi is not very broad, and becomes gradually narrowed, but not much, towards the apex; the second becomes gradually narrowed, on the outer side from the base to the apex, which is transverse and three times the width of the base; the two following are smaller and are not so broad at the apex compared with the base. The basal abdominal segment is broadly black at the base and apex; the two bands are united in the centre by two black marks which become gradually narrowed towards the apex; the apices of the second, third, and fourth are broadly black; the black bands dilated backwards in the middle, and have, at their base, two black marks, which are broader than long; the fifth segment is black, with the sides broadly yellow; the sixth is entirely black, with its sides straight. The ventral segments are black, except the first and second at the sides of the apex; the yellow marks there are obliquely narrowed towards the apex.

The ♂ is similarly coloured; the clypeus is pale yellow, black at the base and with a broad band on the apex; the seventh joint of the antennae is slightly dilated near the apex; the eighth has a stout tooth, which becomes gradually raised from the base to the apex; at the apex is a small one; there is a blunt basal and a smaller, sharper apical one on the ninth; the tenth is broadly dilated behind, as is also, to a less extent, the eleventh. The middle femora are serrate beneath; the joints of the fore tarsi are not so much dilated, especially towards the apex; the spine on the second ventral segment is larger than usual; its downward length is distinctly greater than its length at the base and it is curved and slightly hooked at the apex. The pygidium is sparsely and distinctly punctured on the sides; the epipygium becomes gradually raised in the middle to shortly beyond the centre of the segment, there curves downwards, the top slightly projecting. The last joint of the hinder tarsi is thickly fringed at the base with stiff longish spines, which being longer at the base and apex of the fringed part give it an incised appearance.

11. *Bembex handlirschi*, sp. nov.

Long. 11 mm. ♂.

Hab. Hulule, Male Atoll, Maldives.

This is one of the smallest of the Oriental species. It belongs to the group of *Orientalis*.

Antennae entirely black; the seventh and eighth segments are dilated towards the apex on the underside; the ninth has a small sharp spine; the tenth and eleventh are hollowed; the tenth is narrowed at the base. Head black, thickly covered with white hair; the clypeus, except at the base, and the apex in the centre, the outer orbits, the labrum, the mandibles, except at the apex, two small central and a longer, pyriform mark outside below the ocelli, pallid yellow. Thorax thickly covered with white pubescence; two narrow lines on the centre of the mesonotum and probably a transverse apical one, a narrow line on the pronotum, the base and apex of the propleurae, a curved line on the upper half of the mesopleurae in the centre; this line becoming dilated gradually, but not very much, towards the centre, a small mark on the base of the metapleurae, a large oblique one, narrowed at the base, on the apex and extending on to the apical slope of the segment; the apex of the scutellum and postscutellum and a broad curved interrupted line on the apex of the basal slope of the median segment, pale yellow. Legs coloured like the body; the coxae, trochanters, the base of the femora narrowly and the upper part broadly and the lower parts of the anterior pair and the hinder knees, black; the middle femora are serrate, but not strongly; the joints of the fore tarsi are slender and not much dilated towards the apex; the spines are long and pale. The basal black band on the first abdominal segment is broadly and roundly dilated in the middle at the apex; there are two black marks, broader than long, on the base of the second, two less distinct ones on the third; the apical bands are dilated backwards in the middle; the band on the fifth is united by a narrow line to the base; the 6th and 7th segments are entirely black. There is no spine on the second ventral segment; the last is broadly depressed on the either side of the middle; the outer edge is curved and narrowed towards the apex. Wings clear hyaline; the costa and stigma testaceous; the nervures darker. Tegulae black, lined with black on the inner side.

Fam. **Vespidae.**

12. *Polistes hebraeus* Fab.

Hab. Hedufuri, Mahlos Atoll, Maldives.

The Maldives form is *macaensis* Fab.

13. *Polistes stigma* Fab.

Hab. Minikoi, Laccadives. The common Indian variety.

14. *Rhynchium Maldivense*, sp. nov.

Long. 11—13 mm.

Hab. Hulule, Male Atoll, Goidu, Goifurfehendu Atoll, Maldives. Minikoi, Laccadives.

This species agrees so very closely with *R. argentatum* Fab., *sec.* Saussure, *Stett. Ent. Zeit.* XXIII. p. 187 (cf. Cameron, *Ann. and Mag. Nat. Hist.*, Dec. 1900, p. 531), that it might readily be mistaken for it. It may be known from it by the pronotum behind being sharply keeled, by the propleurae being bordered before and behind by flat, shining keels; the third cubital cellule at the bottom is broader, being as wide there as the space bounded by the first recurrent and the second transverse cubital nervures, whereas in *argentatum* it is not half the length.

♂. Antennae covered with a pale down; the hook is brownish, stout, slightly curved; with its pedicle it is fully longer than the joint. The front, the eye incision, and the lower half of the outer orbits are thickly covered with silvery pubescence; the vertex with griseous hair. The front and vertex are closely and strongly punctured; the space between the antennae bears a narrow, but distinct, keel. The clypeus at its greatest width is nearly as long as its length; above it is transverse and bordered with a yellow band; the upper half is distinctly punctured; the lower is alutaceous and impunctate; the apex is broadly and roundly incised; its sides have an oblique slope. Thorax strongly and closely punctured, except on the apex of the meso- and on the basal half of the metapleurae. The prothorax at the base all round is bordered by a sharp keel; the furrow above the middle of the mesopleurae is distinct; the base below is smooth. The sides of the median segment are broadly rounded and bear neither teeth nor spines; its apex has an almost perpendicular slope and is almost transverse; above in the middle it is very slightly developed; it is smooth, except round the edges; the central furrow is deep and distinct on the upper half. Legs densely pruinose, as is also the abdomen. The basal segment of the abdomen is clearly separated from the second.

The ♀ has the clypeus punctured all over and it wants the white line on the top; it is more convex above and is more broadly and, not quite so deeply, incised at the apex; the median segment is more fully developed, and in the centre it is finely, transversely striated. The wings in both sexes are deeply violaceous.

ANTHOPHILA.

Fam. **Apidae.**

15. *Halictus minikoiensis*, sp. nov.

Niger, dense griseo piloso; tarsis longe fulvo pilosis; alis hyalinis; stigmate testaceo, nervis fuscis. ♀ et ♂.

Long. 8 mm.

Hab. Minikoi, Laccadives.

Antennae black; the flagellum tending to brownish near the apex and covered with a pale pile. The ocellar region is smooth and shining; the rest of the vertex and front closely and distinctly punctured. The face is roundly convex in the middle and is clearly separated from the clypeus; and is there almost impunctate. Clypeus rather strongly, but not very closely punctured, except at the apex, which is transverse; the extreme apex is depressed, brownish in tint and slightly projects at the ends. The hair is griseous, long and moderately thick on the front and face; sparser and shorter on the other parts. Mandibles brownish in the

middle. Mesonotum shining, minutely punctured; in the centre of the basal half is a shallow, narrow furrow. Scutellum punctured on the sides and apex. Post-scutellum thickly covered with long griseous pubescence. The striae on the basal area of the median segment are irregular; at the base they are stouter and longitudinal; at the apex finer, closer and transverse; on the sides they are narrow, close together and longitudinal. The hair on the pleurae is longer and thicker than it is on the upper surface. The hair on the legs is long and white; on the outer side of the tibiae it is shorter and darker, almost black; on the tarsi it is long and bright fulvous; the claws are pale testaceous. Wings clear hyaline, iridescent; the stigma is testaceous; the nervures are blackish; the first recurrent nervure is interstitial. Abdomen shining, impunctate; the segments are edged with white pubescence; there is a narrow transverse furrow on the second and third segments; the anal rima is brownish.

The eyes distinctly converge above; the head is not very elongate in front; the lower half of the front bears a distinct keel; the apex of the median segment has a semi-perpendicular slope, is smooth and shining and deeply furrowed on the lower part; the tegulae are piceous.

16. *Ceratina viridissima* (Dalla Torre) (*viridis* Guer.).

Many of the specimens are golden above.

Hab. Common in the Maldives.

17. *Ceratina appendiculata*, sp. nov.

Nigra, capite thoraceque supra viridis; abdomine late flavo-lineato; clypeo flavo, nigro bilineato; alis hyalinis, nervis stigmateque testaceis. ♀.

Long. 4 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae broadly yellow beneath; the flagellum brownish. Head dark green, smooth, thickly covered with white pubescence; the clypeus and an oblique, somewhat conical, spot close to its lower side, yellow; in the centre of the clypeus are two large marks, longer than broad and rounded above. Mandibles yellow, black at the apex. The mesonotum and scutellum are green; there is a broad yellow line on the pronotum, extending to the tubercles, which are similarly coloured, as are also the post-scutellum and a curved line at the side of the scutellum. The median segment is black and is, at the base, closely obliquely striated. Wings clear hyaline; the stigma and nervures are pale testaceous; the second and first transverse cubital nervures are united at the top. Legs thickly covered with long, white hair; the knees, tibiae and tarsi are bright yellow; the middle tibiae are lined behind with black in the middle; the hinder are black, except at the base and apex. Abdomen smooth and shining; there is a short yellow line on the first segment on either side; on the second and third the yellow lines extend nearly to the middle; on the fourth they are almost united; on the fifth and sixth they are continuous.

Characteristic is the union of the first and second cubital nervures at the top; the third is straight and oblique to near the bottom, where it curves sharply backwards, thus forming a sharp angle, from the apex of which a short nervure issues; the second recurrent nervure is received at the base of this angle.

A distinct species.

18. *Allodape picitarsis*, sp. nov.

Niger, nitidus, facie, clypeo, maculaque inter antennas flavis; alis hyalinis, stigmate fusco. ♀.

Long. 5—6 mm.

Hab. Minikoi, Laccadives.

Antennae black; the flagellum with a brownish tinge towards the apex. Head smooth and shining; the vertex is obscurely punctured. The front ocellus is surrounded by a wide, deep furrow; the front is broadly dilated in the middle; the dilatated part becomes gradually wider towards the apex. The yellow mark on the face is slightly and roundly incised on the top; the sides curve slightly outwardly; the yellow mark is continued to the end of the clypeus, on which it is narrower and slightly longer. On the apex of the pronotum is a broad, white band, narrowed at the sides; the tubercles and the greater part of the tegulae are yellow. Mesonotum and scutellum aciculated; the basal area of the median segment is strongly and closely punctured; the rest of it is smooth and shining. Legs thickly covered with long, white hair; the hair on the tarsi is more testaceous in colour, and their apices are testaceous. Abdomen shining, smooth; the apices of the segments are testaceous; the basal segment at the base is hollowed, but not deeply. Wings clear hyaline; the stigma fuscous; the nervures slightly darker.

19. *Megachile otriades*, sp. nov.

Long. 13 mm. ♀.

Hab. Hitadu, Mahlos Atoll, Maldives.

Has the hair coloration of *M. lanata*, with which it is closely related; it is smaller; the mandibles are differently formed, their second tooth is longer compared to the first and not so widely separated from it; the middle part is broadly and distinctly dilated, the posterior part being also dilated and separated; it is more rounded than the middle portion, which has the base and apex straight and oblique.

Scape of antennae black, opaque, closely punctured and covered with pale hair; the flagellum is brownish. Head as wide as the thorax, closely, almost rugosely, punctured except for a T-shaped mark on the clypeus and face, the end of which extends to the apex of the clypeus. The front is thickly covered with long, dark, rufous hair; the vertex with shorter, dark, fuscous hair; the face and clypeus with long, dark hair. The mandibles are furrowed along the edge to near the base; on the inner part they bear long, curved punctures; the outer tooth is sharply pointed, becoming gradually narrowed to the apex, which is rounded; the second tooth is triangular; the inner is broadly rounded; the middle and the second are bordered behind by a smooth, flat part, which is clearly separated. Thorax closely and distinctly punctured and thickly covered with dark, rufous hair; the sides and breast with shorter pale hair. Legs thickly covered with pale hair; the hair on the hinder tarsi on the inner side is dark rufous. The basal segments of the abdomen are covered with dark rufous, the other segments are fringed with pale, fulvous hair; the scopa is pale, almost white, except on the last segment, where it is black.

20. *Megachile cinyras*, sp. nov.

Long. 15—16 mm.

Hab. Minikoi, Laccadives.

Belongs to Bingham's Section "F. Abdomen with transverse bands on all segments above of white pubescence" (*Hym. of India*, p. 472), in which it would form a new section: Pollen-brush white, black at the apex.

Head closely and rather coarsely punctured; the lower part of the face and the middle of the clypeus broadly and irregularly smooth and shining. Mandibles closely and strongly punctured; the apical tooth is bluntly rounded; the second shorter and more triangular in shape, but not sharply pointed at the apex; next to it is a rounded depression, followed by a longer, straighter one. Thorax closely and strongly punctured and without any striations; the hair above is rufous, on the upper part of the pleurae fulvous; on the lower white. The hair on outer side of the legs is white, on the inner rufous. The basal half of the wings is fulvous; the apical smoky, with a violaceous tinge. The abdominal segments are fringed with pale pubescence; the pollen-brush white, slightly tinged with fulvous; on the apical two segments it is black. The back is shining and has a distinct violet and blue iridescence.

What I consider to be the ♂ has the apical tooth of the mandibles narrower and more sharply pointed; and it is followed by two shorter triangular ones; the hair on the front and vertex is white; the clypeus is fringed with bright, rufous hair; the antennae are long and slender; the apex of the last joint is obliquely narrowed and smooth and shining on the lower side; the last segment is broadly incised, the sides of the incision are straight and oblique; the last ventral segment is irregularly, coarsely, rugosely punctured; its hinder edge is raised and is irregularly toothed.

21. *Xylocopa tenuiscapa* West.

Hab. Goidu, Goifurfehendu Atoll, Maldives. One example.

22. *Xylocopa esica*, sp. nov.

Nigra, nigro pilosa; alis violaceis ♀.

Long. 23 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae narrow, not dilated at the apex; the flagellum covered with a fuscous down. Eyes parallel, only very slightly converging above. Head shortly, but perceptibly, narrower than the thorax; densely covered with black pubescence; closely and rather strongly punctured. The anterior ocellus is surrounded by a smooth furrow, which is widest below, where it is produced downwards for a short distance; the space below it is smooth and shining and ends in a smooth tubercle, which has a small fovea above it. The face and clypeus are closely punctured, are flat, and, at the apex, the clypeus is smooth and shining and almost transverse with the sides rounded; a deep, oblique furrow runs from the base of each antenna, downwards. Mandibles smooth and shining; the base in the middle bears some deep, irregular punctures, below which is a distinct fovea, which is oblique,

straight on the inner side, rounded on the outer, and narrowed beneath; the lower tooth is broadly rounded; the lower somewhat triangular. The labrum in the middle is smooth and shining, bare and broadly keeled, the keel being broadest on the top. The sides and base of the mesonotum are closely punctured, as is also the scutellum, except at the base. The median segment is more closely and strongly punctured; the basal area is clearly defined; its base is longer than the sides; it is aciculated and obscurely furrowed down the middle. The hair on the legs is long, dense and deep black. Wings uniformly deep violaceous, with some blue tints at the base and apex; the third transverse cubital nervure is obliquely sloped at the top and bottom; the two parts are of equal length and form a sharp angle in the middle; the lower part has a more sharply oblique slope. Abdomen smooth and shining; sparsely punctured, except at the base where the punctuation is closer and stronger; there is a smooth furrow down the middle of the apical segment; the middle of the last apical segment is smooth and keeled towards the apex.

This species comes near *X. gardineri*, but is not, I feel sure, its ♀; as, apart from the difference in the coloration of the base of the wings, it differs from it in some structural points; the area on the median segment is longer, much broader compared to its length and it is glabrous and impunctate; the thorax wants the white pubescence; it is smaller and the abdomen at the base is not hollowed: it is distinctly longer than the head and thorax united. The spine on the outer side of the four hinder tibiae is broad at the base, bluntly pointed at the apex; that on the front pair is smaller, more curved and more sharply pointed.

23. *Xylocopa aestuans* Lin.

Hab. Common in the Maldives.

24. *Xylocopa latipes* Drury.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

A common Oriental species.

25. *Xylocopa gardineri*, sp. nov.

Nigra, nigro pilosa, alis violaceis, basi hyalinis. ♂.

Long. fere 25 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae not dilated towards the apex, slender. Head opaque, thickly covered with short black hair and closely and distinctly punctured, except at the sides of the hinder ocelli and the apex of the clypeus. Eyes not converging on the top, parallel. The front ocellus is surrounded by a deep furrow. Clypeus flat; the oblique lateral furrows are not clearly indicated. The base of the mandibles is sparsely punctured; the apical tooth is broadly rounded at the apex; it is short, not much longer than broad. Labrum obliquely depressed, closely and rather strongly punctured and with a smooth furrow down the centre, which is broadest at the top. The sides and base of the mesonotum are covered with pale hair; the centre is bare. Except in the middle the mesonotum is closely and minutely punctured. The scutellum is sparsely punctured at the base, closely and more strongly

towards the apex. Pleurae and sternum closely punctured and thickly covered with black hair. Wings deep violaceous, except at the base, where they are narrowly hyaline. Legs thickly covered with black hair; the outer side of the hinder tibiae is smooth and projects in the middle into a triangular tooth; the inner spur is broadly, triangularly dilated at the base. Abdomen shining; above sparsely punctured at the base, much more closely at the apex. The last ventral segment is bare and smooth and bears a stout tooth on either side, these teeth are straight on the inner side, rounded and narrowed towards the top on the inner; below it is smooth and depressed at the apex. The cubitus beyond the second recurrent nervure is straight, it then turns up straight and obliquely towards the apex of the cellule; it then turns obliquely backwards, this upper abscissa being shorter and having a more rounded curve; the second recurrent nervure has the upper abscissa slightly, the lower (and longer) one is more sharply, oblique. The basal area on the median segment is small, opaque, sparsely punctured; its length is as long as its width at the base.

LAND CRUSTACEANS.

By L. A. Borradaile, M.A., *Lecturer in Natural Sciences of Selwyn College, Cambridge.*

(With Plate III. and text-figures 12—23.)

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I. Introduction.

In the economy of a coral island no group of animals is of greater importance, from the biological point of view, than the land Crustaceans. Their numbers, their ubiquity, their activity combine to give them a prominence, which is all the more marked from the absence of so many of the other land animals of continental areas. They are the chief scavengers of the island, play a great part in the destruction or disintegration of fruits, and probably aid in the distribution of seeds. The work done by them in burrowing along the sandy lagoon shore has a possible importance not hitherto noticed[1]. And it is likely that their omnivorous appetite renders them enemies of many animals, which cannot be specified in the present state of our knowledge: indeed it is highly improbable that the foregoing paragraph exhausts the list of instances in which their behaviour is a factor of importance in the economy of the island[2]. No study of a coral island, in fact, would be complete without an account of this constituent of its fauna.

For five weeks, in the months of June and July, 1899, I was with Mr Stanley Gardiner in the Atoll of Minikoi. During this time I gave considerable attention to the structure and habits of the land crustaceans of the island. My observations form the bulk of the present paper, but there is included a report on the forms collected by the expedition in the Maldives. In treating of Minikoi I shall begin with a short enumeration of the various species to be found there, and the situations in which they respectively live, and then pass on to some remarks on the structure and habits of the land hermit-crabs (*Coenobita*), and the habits of the true crabs of the genus *Ocypode*. The report on the Maldive collection ends the article.

In the section dealing with the genus *Coenobita* I have thought well to enter into some detail, and this for two reasons. First, that the peculiar habits of these animals give them an interest of their own, and thus lend an importance to the investigation of their anatomy, and secondly that, in spite of several excellent descriptions of separate systems of organs to be found in the series of elegant and accurate works on the comparative anatomy of the Decapods which we owe to various French observers, there is still need of an account of the organization of a hermit-crab. In that *Coenobita* presents the Pagurine type in its most highly developed form (at least as regards many of the organs), it is the most suitable genus for this purpose. In that it contains land animals only, and is not found in Europe or temperate North America, it is less so. I have endeavoured to overcome this difficulty by indicating, in the course of the article, those points in which, to my knowledge, *Coenobita* differs from the hermit-crabs of the sea (Paguridae). My dissections have been made on fresh and spirit specimens of the Minikoi species[3] only, and principally on *C. clypeatus* and *C. perlatus*, but, in the few cases where other information has been available, it has been used to check the dissections. Except in a few instances, the musculature has not been dealt with, and histological details have been entirely avoided.

The introduction to this paper would not be complete without an acknowledgment of the generosity of the Drapers' Company of London and of the Managers of the Balfour

[1] See below, p. 95.

[2] See *e.g.* Alcock, *Sci. Mem. Med. Off. Ind.*, XII, p. 59 (1901).

[3] See below, p. 68.

Memorial Fund, by which I was enabled to visit Ceylon and join Mr Stanley Gardiner's expedition, and to undertake, among other pieces of work, that which is here set forth. My best thanks are also due to Mr Stanley Gardiner for much kind advice and assistance, and to Mr Edwin Wilson for the care which he has bestowed upon the illustrations.

II. The Land Crustaceans of Minikoi.

1. General.

The dozen crustacean species living on land in the Island of Minikoi more than make up in number and activity for their comparative poverty in kinds. They are certainly the most conspicuous, as they are probably the most numerous, animals in the island. The Crabs are represented by six species only. Living in burrows, close along the high-water mark of the sandy shore of the lagoon, the sage-green and yellow coloured *Ocypode ceratophthalma* (Pallas) is very numerous. Inland, the place of this species is taken by the brownish *Ocypode cordimana* Desm., whose underground galleries are plentiful in the sandy soil, especially along paths and open spaces. Two species of *Geograpsus*—*G. grayi* (H. M.-Edw.) and *G. crinipes* (Dana)—are common, the former more so than the latter, which seems to like damp spots by the side of pools and tanks of fresh water for which *G. grayi* shows no great preference. These active and conspicuous species, though they are rather hard to distinguish as spirit specimens, are perfectly distinct in life, their colour alone serving to separate them, were there no other differences. *G. grayi* gives the impression of being black and white (in point of fact the back is purple and the legs and underside yellowish), while *G. crinipes* is of a bright orange colour[1].

Another small Grapsid belongs to Kingsley's subgenus *Orthograpsus*[2], which is included by Alcock[3] in the genus *Geograpsus*, Stimps. Unfortunately, a part of the Minikoi collection was damaged on the way home, and there are left of this crab only two badly mangled specimens. So far as can be seen from these, it is near to, but not the same as, Dana's *Grapsus longitarsis*[4]. The points in which the two forms differ are as follows (fig. 12):—1. In the Minikoi specimens the teeth on the underside of the outer end of the meropodites of the walking legs are low and blunt, and much less marked than in Dana's figure. 2. The same is the case with the tooth at the end of the upper edge of this joint. 3. The hairy line along the dactylopodites of the walking legs is wanting. 4. The tooth at the outer angle of the orbit is shorter than in *G. longitarsis*. It shields only about a fourth of the cornea, instead of more than a half, as in Dana's figure. The colour of the crab when alive is a dull brownish-green, and is not much altered by preservation in spirit. The length is about half an inch.

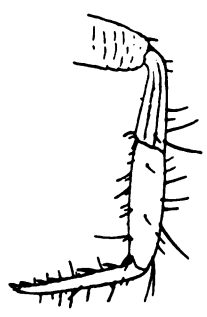


Fig. 12. Second walking leg of right side of *Geograpsus longitarsis*, var. *minikoiensis*.

In the absence of better material, I am unwilling to give any opinion as to the specific distinctness of this little crab. In the list below[5], it will appear as a variety (*minikoiensis*) of Dana's species.

The last of the crabs, the little *Metasesarma rousseauxi* H. M.-Edw., is

[1] For a careful discussion of the differences between these species, see De Man, *Zool. Jahrb. Syst.* IX. pp. 80 ff. (1895).

[2] Kingsley, *P. Acad. Philad.* 1880, pp. 180, 194 (1880).

[3] Alcock, *Journ. As. Soc. Bengal*, LXIX. ii. 3, p. 394 (1900).

[4] For references to literature see below, p. 68.

[5] p. 67.

found in various situations, generally taking advantage of the shelter of some object. It often hides under timber, where, as Dr Alcock remarks[1], its greenish mottled coloration is protective. De Man records[2] some examples of this species from a stream in Flores, but it is certainly not restricted to the water, nor even to particularly damp spots. With the exception of *Geograpsus longitarsis*, all the above crabs are included by Major Alcock among the Indian Fauna[3].

The land hermit-crabs (genus *Coenobita*) are no less numerous than the true crabs on Minikoi. Three species are found—*C. perlatus* H. M.-Edw., *C. rugosus* H. M.-Edw. and *C. clypeatus* Latr. Of these the first two show a preference for the neighbourhood of salt water, while the third is chiefly to be found in the jungle. I shall return, later on, to the subject of the genus *Coenobita*.

Three species of Isopod make up the tale of Minikoi land Crustaceans to twelve. Two woodlice, belonging respectively to the genera *Cubaris* and *Philoscia*, are found, as might be expected, in rotten timber and loose earth, while a *Ligia* (*L. exotica* Roux) lives in certain localities along the lagoon shore, and is chiefly conspicuous in running about on boats drawn up on the beach.

The following is a complete systematic list of the land Crustacea of Minikoi:—

DECAPODA, BRACHYURA, CATOMETOPA.

Family **Ocypodidae.** Genus *Ocypode*, Fabr., 1798[4].

1. *Ocypode ceratophthalma* (Pallas), 1772.
   Cancer ceratophthalmus, Pallas, Spicilegia Zool. IX. p. 83, pl. V. figs. 7, 8 (1772).
   Ocypoda ceratophthalma, Ortmann, Zool. Jahrb. Syst. X. p. 365 (1897) [synonyms]; Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 345 (1900).

2. *Ocypode cordimana* Desm., 1825.
   Ocypoda cordimana, Desmarest, Consid. gen. Crust. p. 121 (1825); Ortmann, Zool. Jahrb. Syst. X. p. 362 (1897) [synonyms]; Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 349 (1900).

Family **Grapsidae.** Genus *Geograpsus*, Stimps., 1858.

3. *Geograpsus grayi* (H. M.-Edw.), 1853.
   Grapsus grayi, H. Milne-Edwards, Ann. Sci. Nat. Zool. (3) XX. p. 170 (1853).
   Geograpsus grayi, Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 395 (1900) [synonyms].

4. *Geograpsus crinipes* (Dana), 1851.
   Grapsus crinipes, Dana, Proc. Ac. Philad. 1851, p. 101.
   Geograpsus crinipes, Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 396 [synonyms].

[1] Alcock, *op. cit.*, p. 428.
[2] De Man, Max Weber's "Reise O. I." II. p. 350 (1892).
[3] Alcock, *op. cit.*, *passim*.
[4] Ortmann [*Zool. Jahrb. Syst.* X. p. 359 (1897)] states that Fabricius spelt this name *Ocypoda*. In the copies of the *Ent. Syst. Suppl.* in the Cambridge University and Zoological Society's libraries the spelling is *Ocypode*.

5. *Geograpsus longitarsis* (Dana), 1851, var. *minikoiensis* n. (fig. 12).
Grapsus longitarsis, Dana, Proc. Ac. Philad. 1851, p. 249; U.S. Expl. Expd. Crust. I. p. 339, pl. XXI. fig. 4 (1852).
Orthograpsus longitarsis, Kingsley, Proc. Ac. Philad. 1880, p. 195.

Genus *Metasesarma*, H. M.-Edw., 1853.

6. *Metasesarma rousseauxi* H. M.-Edw., 1853.
Metasesarma rousseauxi, H. Milne-Edwards, Ann. Sci. Nat., Zool. (3) XX. p. 188 (1853); De Man, Zool. Jahrb. IX. Syst. p. 138 (1895); Alcock, Journ. As. Soc. Bengal, LXIX. ii. 3, p. 427 (1900).

ANOMALA, PAGURINEA.

Family **Coenobitidae.** Genus *Coenobita*, Latr., 1826.

7. *Coenobita perlatus* H. M.-Edw., 1837.
Cenobita perlata, H. Milne-Edwards, Hist. Nat. Crust. II. p. 242 (1837); Id. Atlas to Crust. Cuvier's R. An. pl. XLIV. fig. 1.
Cenobita perlatus, Ortmann, Zool. Jahrb. Syst. VI. p. 319 (1892) [synonyms].

8. *Coenobita rugosus* H. M.-Edw., 1837.
Cenobita rugosa, H. Milne-Edwards, Hist. Nat. Crust. II. p. 241 (1837).
Coenbita rugosus, Ortmann, Zool. Jahrb. Syst. VI. p. 317, pl. XII. fig. 22 (1892) [synonyms].

9. *Coenobita clypeatus* Latr., 1826. (Fig. 13.)
Coenobita clypeata, Latreille, Fam. Nat. R. An. p. 277 (1826).
Coenobita clypeatus, Ortmann, Zool. Jahrb. Syst. VI. p. 315, pl. XII. fig. 20 (1892) [synonyms].

ISOPODA, ONISCOIDEA.

Family **Armadillidiidae.** Genus *Cubaris*, Brandt, 1833.

10. *Cubaris murinus* Brandt, 1833.
Cubaris murinus, Brandt, Consp. Onisc., Bull. Soc. Nat. Mosc. VI. p. 190 (1833).
Armadillo murinus, Budde-Lund, Crust. Isop. Terrestr. p. 27. Hauniae, 1885 [synonyms].

Genus *Philoscia*, Latr., 1803.

11. *Philoscia*, sp.
Near *P. gracilis* Budde-Lund, 1879, but cannot be more accurately determined, as the single specimen now available for examination is in a somewhat damaged condition, and has lost both uropods.

Family **Ligiidae.** Genus *Ligia*, Fabr., 1798.

12. *Ligia exotica* Roux, 1828.
Ligia exotica, Roux, Crust. Médit. 3, pl. XIII. fig. 3 (1828); Budde-Lund, Crust. Isop. Terrestr. p. 266. Hauniae, 1885 [synonyms].

2. SOME POINTS IN THE STRUCTURE AND HABITS OF THE LAND HERMIT-CRABS (*Coenobita*).

i. **External features.**

The genus *Coenobita* contains those hermit-crabs which have left the sea and taken to a life on land, but have not, like *Birgus*, lost the habit of shielding the abdomen with a shell, or some such covering. In their outer, as in their inner organisation, the members of the genus closely resemble the hermit-crabs of the sea, and even present many

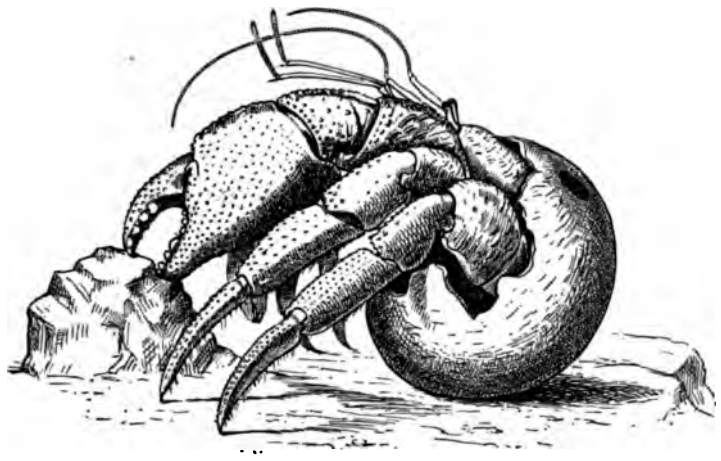


FIG. 13. *Coenobita clypeatus* using a broken coconut as shell.

characteristic features of Pagurine[1] structure in a more highly developed form than any other branch of the group. The most striking of these features are, of course, those connected with the habit of sheltering within the empty shell of a gastropod mollusk, and it is perhaps worth while recapitulating them, even at the risk of ploughing the sands of well-known fact.

Physiologically, then, the body may be divided into three regions as regards its outward aspect: (1) a *fore-part* carrying the complex of organs—sensory structures, legs and jaws—by which the animal enters into relation with the outer world, and containing internally the central nervous system and stomach, both intimately connected with the external organs just mentioned, and the excretory organs. This part of the body can be completely extruded from the shell, while the animal still retains a firm hold on the latter. (2) A *mid-part*, which, when the fore-part is thrust out, fills the mouth of the shell, and is provided with limbs, which help in retaining a grasp of it. This region carries the main respiratory apparatus—delicate organs which need a certain amount of protection and yet should be in free communication with the surrounding medium—and the heart. (3) A *hind-part*—the abdomen—which contains the bulky liver and the generative organs, and carries on its appendages the eggs, which thus obtain the shelter provided by the shell. This division of the body, which is at all times completely protected by the shell, is also provided with an apparatus by means of which, in normal circumstances, the latter is retained. This apparatus consists of an anchor, formed by the sixth abdominal segment and its appendages (fig. 18), and a broad band of muscle—the cable of the anchor—along the ventral side of the abdomen, serving roughly the same purpose as the columella muscle of the original maker of the shell.

[1] In the present article, the term "Pagurine" will be used to include the most typical members of the Paguriness—the Paguridae and the Coenobitidae. The word "Pagurid" will be applied to the former of the two families alone.

The *fore-part of the cephalothorax* is strongly compressed, having a narrow, vaulted roof and flat vertical sides. Its compression extends also to the antennae and the first three pairs of legs, enabling the whole complex, including the limbs, to be withdrawn into shelter when necessary. The absence of the rostrum is, no doubt, an adaptation to the same end. The cuticle over the whole of these exposed structures is strongly calcified.

The *eyestalks* are narrow and elongated and directed straight forwards above the antennules; the eyes themselves are small. Some rather abnormal features appear in the *antennules* (fig. 14). By the lengthening of their joints, the stalks of these appendages far outreach those of the antennae, bearing at their ends each a long and a short flagellum, the whole being able to be folded up lengthwise and concealed under the body. The long flagellum, which is the more dorsal of the two, is compressed and club-shaped, with a blunt, rounded end. Its lower edge is covered, in the distal two-thirds, with a close fur of short "olfactory" hairs[1]. The short flagellum tapers at the end, and bears on the penultimate joint a long bristle, which looks as if it were adapted for cleaning the olfactory hairs of the long flagellum. The opening of the otocyst is small, but situated in its usual position on the dorsal side of the basal joint of this limb. The antennules of the Pagurids (fig. 14), on the other hand, are relatively short, and bear each two short flagella, like those of the crabs. The dorsal (outer) flagellum tapers to a point and bears below a fringe of olfactory hairs much longer than those of *Coenobita*. These peculiarities of *Coenobita* are perhaps in connection with the habit of exercising the sense of smell in the search for food[2], and that in a different medium from the one in which the Paguridae live, while at the same time it is necessary that the organs be able to be withdrawn into a small space.

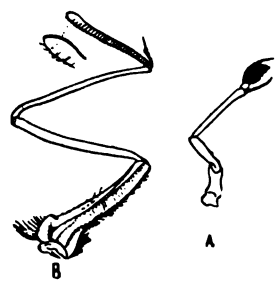


FIG. 14. Left Antennules. A. *Eupagurus bernhardus*; B. *Coenobita clypeatus*.

The scale of the *antenna* (fig. 15), which in the Pagurids is well developed and moveable, is, in *Coenobita*, reduced in size and, except in one instance[3], fused with the second joint of the flattened stalk of the limb. The flagellum ends bluntly instead of tapering to a point like those of most marine Decapods—a feature, which must probably be attributed to the same cause, which has shortened the sensory hairs of the antennule. The *mouth-limbs* (fig. 16) present no remarkable features. They are all stout and show a tendency to develope tufts and fringes of strong, close set, hairs. The powerful cutting edge of the mandible is not toothed, and the lash of the exopodite of the first maxilliped is wanting.

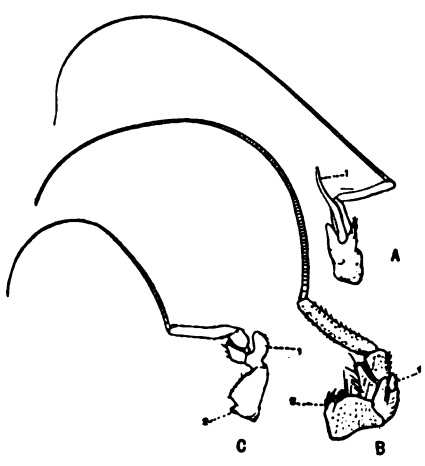


FIG. 15. Left Antennae. A. *Eupagurus bernhardus*; B. *Coenobita clypeatus*; C. *Coenobita perlatus*. 1. Antennal scale. 2. Tubercle with opening of green gland (not seen in A).

[1] The statement of Ortmann [Bronn's *Thierreich*, v. 2, p. 1146] that these appendages "langen Sinneshaare entbehren" is thus somewhat misleading, though strictly true. The shortness of the hairs, which would be apt to become matted in the absence of a supporting medium such as water, is no doubt an adaptation to terrestrial life.

[2] See below, p. 92.

[3] *C. clypeatus*, Latr.

The *legs* (figs. 13 and 17) of the first pair are unequal, though both are chelate. The larger, left chela, used for seizing and holding the food and as a weapon of offence and defence, serves, when the animal is withdrawn into the shell, as a very perfect lid or operculum, for which purpose its stout, rounded shape is clearly adapted. It may also (*C. rugosus* A, fig. 17) bear a stridulating organ in the form of a series of parallel ridges on its outer surface. The smaller chela is used for tearing the food and conveying the fragments to the mouth. The second and third pairs of legs are adapted for walking.

The *hinder part of the thorax*, forming the middle of the three regions alluded to above, may be said to begin at the level of the transverse portion of the cervical groove and to include the two hinder pairs of legs. It is distinguished from the preceding region by

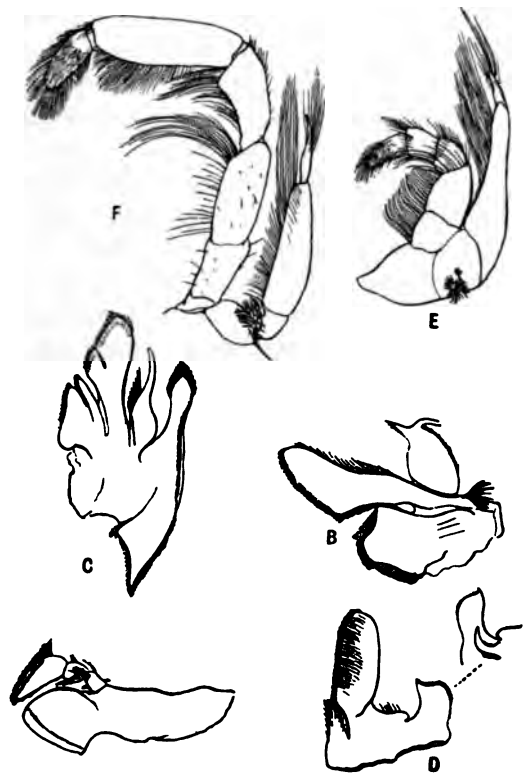


FIG. 16. Mouth-limbs of the left side of *Coenobita clypeotus* from behind. A. Mandible; B. 1st maxilla; C. 2nd maxilla; D. 1st maxilliped; E. 2nd maxilliped; F. 3rd maxilliped. A small portion of the anterior side of D is attached to show the endopodite.

In *Pagurus* the maxillipeds bear on their exopodites long, slender, curved lashes, fringed with fine hairs and much resembling those of many crabs. The absence of these structures in *Coenobita* is perhaps due to the loss of their functions in the absence of water. The little backward hook on the first maxilla is wanting in *Pagurus*.

being rather depressed than compressed and by less strong calcification of its integument. The branchiostegites, which anteriorly share in the general compression and calcification of the body, are here soft and tend to be depressed. But the legs of the fourth pair are carried pressed up against the sides of the body in such a way that the soft branchiostegites are indented by them and only project dorsally and posteriorly where they overhang the limbs in question. Behind, the branchiostegites gape widely from the body, and leave an opening, through which the legs of the fifth pair can be thrust into the gill chamber.

The *fourth and fifth legs* (B—E, fig. 17) of each side are markedly smaller than the preceding ones. Each of them is chelate after its own fashion, and each bears a part in the work of holding the animal into its shell. This is accomplished by means of a definite patch on the propodite of the limb, which is covered with a fine sculpture in the form of rounded scales, overlapping one another so as to produce a surface capable of friction. In cases, which often occur, when the animal, either from its size, or from the lack of suitable gastropod shells, is forced to content itself with some other receptacle for its abdomen[1], these limbs have to take a larger share of the work in which they ordinarily assist the sixth abdominal appendages, of keeping on the "house." It is probably by their means also that the animal is able to emerge from the shell when it is inverted. The chela of the *fourth leg* is of a peculiar nature. The propodite, on which the above-mentioned patch is developed, is a broad, discoidal structure. Against this disk fits a little sickle-shaped dactyle. In *Pagurus* the limb more nearly approaches a normal chela, in *Eupagurus* it is sub-chelate. The *fifth leg* has a chela which is clumsy, but of the ordinary shape, with two approximately equal fingers. As in the other forms (Anomala) in which it is a gill-cleaning organ, it is covered with hairs and usually carried under the branchiostegite during life, though upon occasion it can be used to assist in retaining hold of the shell.

FIG. 17. Legs of hermit-crabs from left side. A. 1st leg (cheliped), *Coenobita rugosus*; B. 4th leg, *Eupagurus bernhardus*; C. 4th leg, *Pagurus deformis*; D. 4th leg, *Coenobita clypeatus*; E. 5th leg, *Coenobita clypeatus*. 1. Stridulating organ. 2. Male generative opening.

The *abdomen* is connected by a narrow waist with the thorax. It is covered with a soft, flexible skin, save for a narrow transverse ridge representing the tergite of each of the first five abdominal segments, and broader plates on the sixth segment and telson. The whole is spirally twisted to the right, to fit in with the dextral twist of an ordinary gastropod shell. In correspondence with this twist, the appendages are also asymmetrical. In the male they are absent from the first five segments[2], but in the female the second, third and fourth are provided, on the left side with long, biramous limbs, covered with hairs and used in the breeding season for carrying the eggs. The sixth pair of abdominal limbs (fig. 18) are present in both sexes, but that of the right side is larger than that of the left. The exopodite is sickle-shaped and longer than the endopodite; both are provided, on the outer surface, with friction organs like those of the last two thoracic legs, and the function of the whole limb is obviously to anchor the animal into its shell.

[1] *e.g.* the shell of the fruit of *Calophyllum* or of the coconut. See p. 92.

[2] *C. clypeatus* has short, uniramous limbs on the left side in the 2nd, 3rd and 4th abdominal segments of the male.

The family Coenobitidae, containing besides *Coenobita* the Robber-Crab *Birgus*, differs from the Pagurids, or hermit-crabs of the sea[1], in the following external features:—1. The

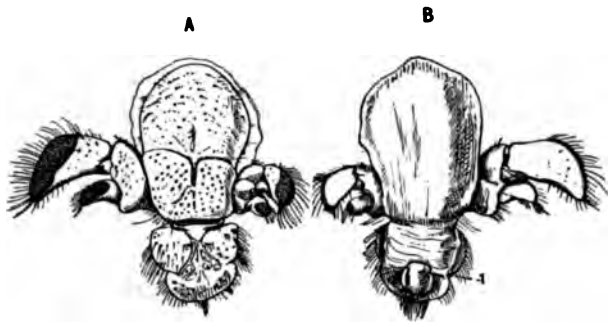


FIG. 18. Last two abdominal segments of *Coenobita clypeatus*. A. Dorsal view; B. Ventral view. 1. Valve guarding the anus.

structure of the antennules (*see above*). 2. The structure of the antennae (*see above*). 3. The greater compression of the fore-part of the body. 4. The habitat—on land.

The genus *Coenobita* differs from *Birgus* in the form of the abdomen, which in *Birgus* is short, untwisted, provided with broad terga, and not carried in a shell. The points in which the outward features of *Coenobita* vary from species to species are small and unimportant. The most interesting is perhaps that which separates *C. clypeatus* Latr. from the rest of the genus. In this species the vestige of the antennal scale is still loosely articulated with the stalk. In all the others it is fused. *C. diogenes* (Catesby) is distinguished by its cylindrical eyestalks from the other species, in which these structures are always compressed. Of the remaining four forms, *C. rugosus* H. M.-Edw. and *C. perlatus* H. M.-Edw. are distinguished from *C. compressus* Guérin and *C. spinosus* H. M.-Edw. by the elongation of the basal joint of the fifth leg of the male into a genital process, and by the presence of stridulating ridges on the outside of the hand (propodite). The small grey or purple *C. rugosus* is very variable (Bouvier[2] enumerates several varieties), but may be easily distinguished from the larger, scarlet, *C. perlatus* by the greater development in the latter of the genital process. *C. compressus* is recognisable by its small size, grey, or purple colour and less hairy integument from *C. spinosus*, which is larger, of a brown colour, and considerably hairy in parts. The last revision—and the one adopted in this paper—is to be found in Ortmann's well-known work on the Decapods of the Strassburg Museum[3]. It differs in several points from that of Bouvier[4], but has the merits of simplicity and clearness, and has satisfactorily accounted, so far, for every one out of the many specimens that have passed through my hands.

The distribution of the genus would appear, from the data in Ortmann's paper and others since published, to be as follows:—*C. diogenes* is found in the West Indian region alone, and is the only representative of the genus there. The other species are all restricted to the Indo-Pacific area, but are there of almost universal distribution, *C. rugosus* being perhaps the most widespread.

[1] See footnote to p. 69 above.
[2] Bouvier, *Bull. Soc. Philem.*, Paris, (8), II. p. 143 (1890).
[3] Ortmann, *Zool. Jahrb. Syst.*, VI. p. 315 (1892).
[4] Bouvier, *loc. cit.*

ii. **The Alimentary Canal.**

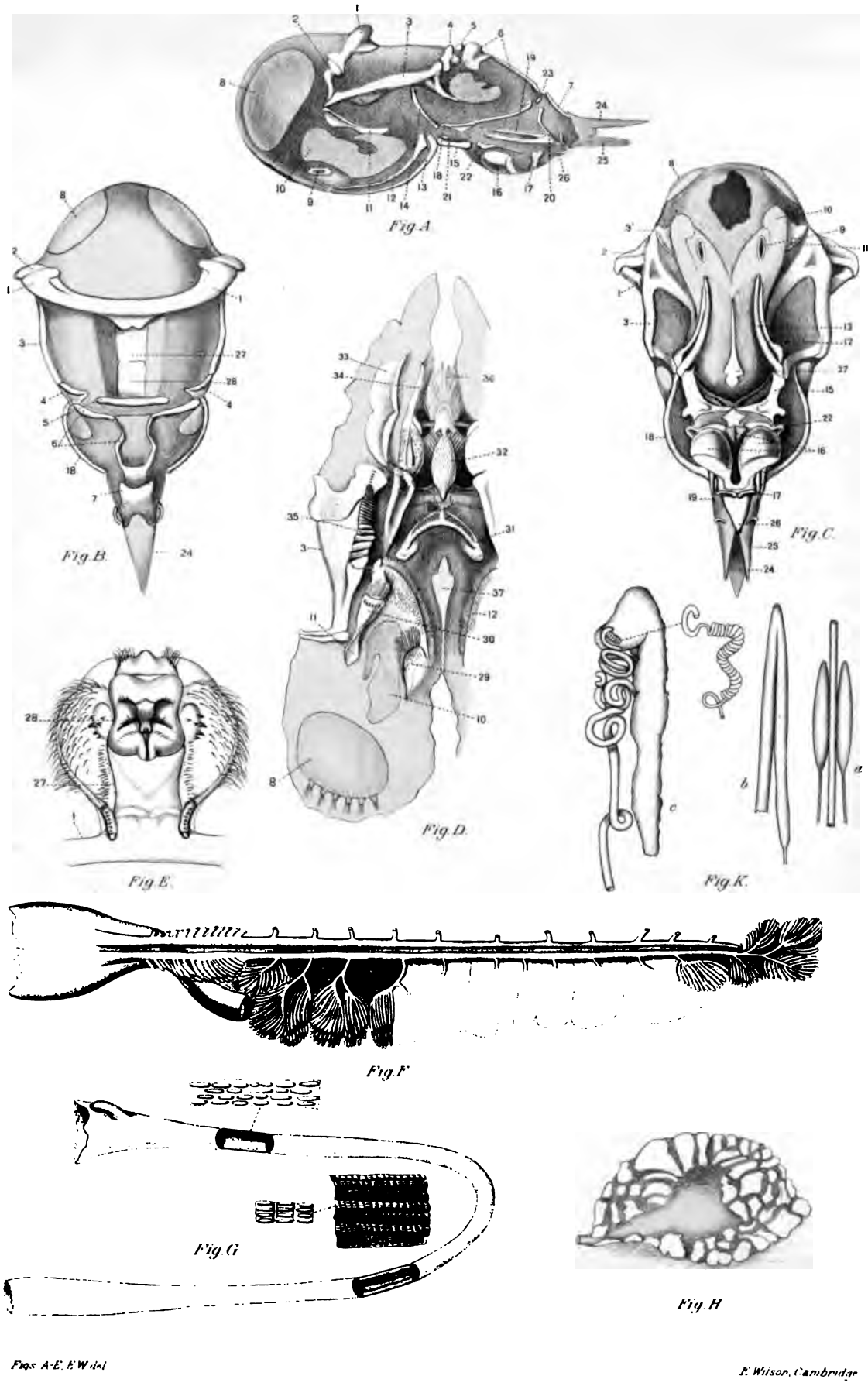
A. The Fore-gut[1]. (Pl. III. figs. A—E). The short, wide *oesophagus* presents no feature of special interest. In correspondence with the compression of the fore-part of the cephalothorax mentioned above[2], the *Maw* or "*Stomach*" is narrow and elongated. The hinder or "pyloric" division is nearly horizontal, and is sundered from the anterior "cardiac" portion by the usual deep hollow on the dorsal surface of the stomach. The *cardiac sac* is narrow, rounded in front and somewhat flattened above. The walls of its thin fore-part show on each side the thickened "cardiac disk" found in other Pagurinea (8, Pl. III.). Internally, this disk bears seven or eight tufts of long hairs, placed on pointed prominences arranged along its lower edge.

The *gastric mill* is strong, no doubt in connection with the nature of the food, which is chiefly vegetable, and often consists of such tough substances as the fruits of the screw-pine (*Pandanus*). In the *mesocardiac ossicle* (1, Pl. III.), the most prominent part is a strong band across the roof of the cardiac division of the stomach, bent in the form of a bow, and lying with the hollowed side forward; its ends are broadened. In front of this is a thinner portion, which merges gradually into the thin wall of the fore-part of the stomach. Behind the ossicle the roof of the stomach falls away into the hollow between the two divisions. The rounded hinder edge of the bow projects somewhat over this gap, and overhangs a wide, triangular process from its own underside, which forms part of the hind wall of the cardiac portion—the anterior wall of the hollow. The apex of this triangular plate, by which it joins the fore end of the urocardiac ossicle, is not pointed, but ends in two rounded lobes, of a bright white colour and strongly calcified. The *pterocardiac ossicles* (2, Pl. III.) are triangular or rather three-lobed structures in the side wall of the cardiac division, at the outer ends of the bow of the mesocardiac. One lobe is directed outwards, one inwards, and one downwards. Between the outward and the inward lobes lies that edge of the ossicle which articulates with the broadened outer end of the mesocardiac bow. The *zygocardiac ossicles* (3, Pl. III.[3]) also lie in the side walls of the stomach, but behind the mesocardiac. Each is a roughly diamond-shaped plate of large size, placed so that its longer diagonal runs fore and aft. There are thus an anterior and a hinder angle. The latter is directed somewhat downwards, so that, of the two edges of the diamond which are uppermost, the hinder slopes downwards, while the more anterior is almost horizontal. This latter edge is much thickened and curled inwards, towards the cavity of the stomach. The other edges are also thickened, though not to the same extent. The *lateral tooth* (35, Pl. III.), borne internally by the zygocardiac ossicle of each side, is strong, and bears a series of transverse ridges which grow smaller from before backwards. The first three or four of these are much larger than the hinder ones, and are set farther apart.

[1] In writing the following account of the fore-gut and its armature in *Coenobita*, I have been much helped by Mocquard's work on these organs of the Decapoda [*Ann. Sci. Nat.* (6) *Zool.* XVI. i. (1883)], and especially by the numerous allusions to this genus scattered through his section on the Pagurinea. Though he figures no *Coenobita*, Mocquard had dissected three species—*C. compressus*, *C. spinosus*, and a third whose name he did not know. The present account is based on the information given by Mocquard and on dissections of the three Minikoi species. Thus the total material available has reference to at least five out of the six species of the genus.

[2] p. 70.

[3] This ossicle is so placed that it overhangs and presents one face downwards and an edge (the horizontal one) outwards. Its shape is therefore not properly seen in a full side view and cannot be made out in fig. A, Pl. III. but may be seen in the ventral view (fig. C).



Borradaile - Coenobita.

The *exopyloric ossicles* (4, Pl. III.), which lie in the roof of the pyloric division of the stomach to the outside, and rather in front, of the medium pyloric ossicle, bearing to this latter much the same relation that the pterocardiacs bear to the mesocardiac, are stout, broad, and roughly diamond-shaped. One diagonal runs transversely and the other fore and aft. The hinder angle is rounded. The whole ossicle has a saddle-like double curvature, and its outer surface is roughened. The *pyloric ossicle* (6, Pl. III.) consists of two parts—an anterior expansion, and a hindward median process from this. The anterior expansion lies with its long axis across the stomach. Its outer ends are thickened, and so shaped as to embrace the ends of the prepyloric ossicle. These thickenings each send backward a very narrow strip to border the hindward process of the ossicle. The whole middle region of the ossicle, between the thickenings, is thin, and of a membranous, or, in the hinder part, cartilaginous consistency.

The *urocardiac ossicle* (27, Pl. III.) is an oblong, semi-transparent plate, of simple form, lying in the anterior wall of the dorsal hollow of the stomach, with its long axis fore and aft. Its anterior end abuts on the mesocardiac ossicle, from which, however, it is

EXPLANATION OF PLATE III.

Reference Numbers.

1. Mesocardiac ossicle
2. Pterocardiac ,,
3. Zygocardiac ,, horizontal (upper) edge
3'. Zygocardiac ,, anterior angle
4. Exopyloric ,,
5. Prepyloric ,,
6. Pyloric ,,
7. Uropyloric ,,
8. Cardiac disk ,,
9. Opening of invagination to bear postoesophageal brush
10. Cardiac side plate
11. Prepectinate ossicle
12. Pennate ,,
13. Inferolateral cardiac ossicle
14. Subdentary ossicle
15. Auricular ,,
16. Ampullar ,,
17. Posterior subampullar ossicle
18. Anterior pleuropyloric ,,
19. Middle pleuropyloric ossicle
20. Posterior ,, ,,
21. Anterior subampullar ,,
22. Middle ,, ,,
23. Posterior mesopyloric ,,
24. Dorsal terminal valve
25. Lateral ,, ,,
26. Ventral ,, ,,
27. Urocardiac ossicle
28. Median tooth
29. Postoesophageal brush
30. Comb
31. Median inferior tooth
32. Interampullary process
33. Upper pyloric side-valve
34. Lower ,, ,,
35. Lateral tooth
36. Interampullary valve (overlying ventral terminal valve)

Fig. A. Stomach of *Coenobita perlatus* from the left side.

Fig. B. Ditto, from above.

Fig. C. Ditto, from below.

Fig. D. Ditto, with roof of cardiac portion removed and the pyloric portion opened along the middle of the roof, the side walls being reflected.

Fig. E. Median tooth of same from within.

Fig. F. Liver of *Coenobita clypeatus*, ventral view.

Fig. G. Mid- and hind-gut of same species; portions opened to show texture of lining.

Fig. H. Green gland of same species from above.

Fig. K. Generative glands; *a*, ovaries of *Coenobita clypeatus*; *b*, ovaries of *C. perlatus*; *c*, testis of *C. clypeatus*. Anterior end towards bottom of plate in each case.

sharply marked off. The *median tooth* (28, Pl. III.), is large and well-developed. It is an oblong plate, somewhat shorter than the urocardiac ossicle, at the hinder end of which it is placed, and with concave sides. The inner surface bears a median longitudinal and four or five pairs of lateral transverse ridges, of which the two hindermost are the stoutest. The details vary considerably in different species[1]. The *prepyloric ossicle* (5, Pl. III.) is a T-shaped structure, placed vertically in the front wall of the pyloric division of the stomach, *i.e.* in that wall which faces the hollow between the two divisions. The stem of the T has concave sides and broadens considerably, where it joins the cross-piece. The latter is slightly concave on its anterior side.

The ossicles described in the foregoing paragraphs constitute the gastric mill, and, with the muscles which move them, are the apparatus by which the food is triturated. To complete the account of the skeleton of the stomach it is now necessary to mention certain less important pieces, by which the organ maintains its shape, and which support internally the various tufts and fringes of hairs with which it is provided. We may consider these in four groups:—

(1) Those of the cardiac region, all of which lie in the ventral, or ventro-lateral wall. They comprise the cardiac disks (described above), the post-oesophageal brushes, the cardiac side-plates, the prepectinate ossicles, the combs, subdentary, pennate and inferolateral cardiac ossicles, and the cardiopyloric valve.

(2) Those on the ventral wall of the pyloric region; comprising the auricular, anteroinferior pyloric, preampullar, and posterior subampullar ossicles.

(3) Those at the sides of the pyloric region; comprising the anterior, middle, and posterior pleuropyloric and anterior and middle subampullar ossicles.

(4) Those in the dorsal wall of the pyloric region; comprising the mesopyloric and uropyloric ossicles.

Group 1. *Postoesophageal brushes* (29, Pl. III.). A patch of hairs on each side of the stomach, situate on a lobe formed by invagination of the wall on the ventral side, a little behind the oesophagus. The outer opening of the invagination is surrounded by a calcified ring.

Cardiac side-plates (10, Pl. III.). Large thickenings of the ventrolateral wall behind the oesophagus. They are covered internally with tufts of hairs, especially long towards the hinder end.

Prepectinate ossicles (11, Pl. III.). Elongated plates in the side wall of the stomach, above the cardiac side-plates. The fore end of each is thin and expanded and the upper edge thickened along its whole length, but especially at the hinder end.

Combs (30, Pl. III.). An invagination of the wall of the stomach at the hind end of the prepectinate ossicle of each side, producing internally a cushion on which are a number of short, stout spines.

Pectinate and post-pectinate ossicles are wanting.

Subdentary ossicles (14, Pl. III.). A slender bar running backward and downward on each side from the zygocardiac ossicle to the fore end of the anterior subampullary ossicle, with which and not with the inferolateral cardiac ossicle, it articulates.

Pennate and inferolateral cardiac ossicles (12 and 13, Pl. III.). Two slender bars running parallel with one another along the line of junction of the ventral and lateral walls of the stomach, which line is defined by their presence. At their hinder ends they curve upwards, in corre-

[1] See Mocquard, *op. cit.*, p. 131.

spondence with the diminishing height of the cardiac division. Each of them grows gradually broader from before backwards, and is expanded at its posterior end. The ventral surface of the stomach, between the two inferolateral cardiac ossicles, is thickened on each side into a plate of cartilaginous consistency. In the middle line these two plates are sundered by a strip of thin chitin, in which lies a median ossicle having the shape of a dagger, placed lengthwise with the blade forwards. The pennate ossicle, which is the more dorsal of the two, bears internally a fringe of long hairs.

Cardiopyloric valve (31, Pl. III.). This has the form peculiar to the Pagurinea and Galatheinea; that is to say, it bears a V-shaped elevation composed of close-set lamellae not unlike the ridges of a file. The lamellae are flexible and the point of the V is backwards. The whole structure is known as the "median inferior tooth."

Lateral cardiopyloric ossicles are wanting.

Group 2. *Auricular ossicles* (15, Pl. III.). A pair of stout troughs, running backwards and inwards from the hinder ends of the inferolateral cardiac ossicles, on the ventral side of the stomach. The hollow of the trough is towards the inside of the stomach, and the hind end of each is expanded and less stout than its fore-part. There are no auricles.

Anteroinferior pyloric ossicles. A semi-transparent, four sided, median plate with a triangular projection from the middle of its fore edge. Behind it, and separated from it by the inner ends of the preampullar ossicles, are two small, semi-transparent, triangular plates, one on each side of the middle line.

Preampullar ossicles. Semi-transparent, transverse plates, just in front of the ampullae on the floor of the pyloric division.

Posterior subampullar ossicles (17, Pl. III.). Stout transverse bars, one on each side just behind the ampullae. Their inner ends are expanded and meet, but do not fuse.

Group 3. *Anterior pleuropyloric ossicles* (18, Pl. III.). Each of these starts at its hinder end by a roughly triangular expansion, with the apex directed downward and forward. From this apex proceeds a stout ridge on the side wall of the stomach, which, running forward, ends by articulating with the ventral end of the subdentary. The lower side of the ridge bears a triangular expansion. In the space between this ossicle and the pyloric, the wall of the stomach is thickened to form a cartilaginous plate.

Middle pleuropyloric ossicles (19, Pl. III.). A slender horizontal rod, behind and below the preceding ossicle on each side.

Posterior pleuropyloric ossicles (20, Pl. III.). A short, curved bar, with the convexity forwards, behind the middle pleuropyloric of each side.

Anterior subampullar ossicles (21, Pl. III.). An elongated calcified strip, hollowed on the outer surface, lying above the auricular ossicle of each side.

Middle subampullar ossicles (22, Pl. III.). Thickenings of irregular form, bearing to the ampullae the same relation that the anterior subampullars do to the auricular ossicles.

Group 4. *Uropyloric ossicle* (7, Pl. III.). A broad median plate in the pyloric roof, with the anterior edge very concave, and the anterior angles produced and strongly calcified.

Mesopyloric ossicles. The anterior pair are wanting; the hinder ones (23, Pl. III.) are present as a small oval plate on each side, in front of the uropyloric and outside its produced fore angles.

Internally the pyloric division presents the usual filtering apparatus of valves and fringes without any remarkable features. Of the *terminal valves* the dorsal and lateral are much elongated and pointed.

It will perhaps be of interest here to indicate the bearing of the gastric armature just described on the systematic position of the genus[1]. The following characters belong especially to the fore-gut of the Pagurinea:—(i) The long, narrow shape of the stomach. (ii) The slight inclination of the pyloric region. (iii) The form of the mesocardiac ossicle. (iv) The longitudinal direction of the dorsal edge of the zygocardiac ossicle. (v) The elongation of the cardiac side plates. (vi) The almost horizontal direction of the pennate and inferolateral cardiac ossicles.

Within the Pagurinea, the following characters separate the Coenobitidae[2] from the Paguridae: (i) The lower edge of the cardiac disk has its hairs arranged in tufts on pointed projections of the body of the disk. (ii) The lateral tooth has no notch on its lower edge. (iii) The median tooth carries transverse ridges. (iv) The exopyloric ossicles have a strong saddle-shaped curvature. (v) The pyloric ossicle is expanded and strengthened at its anterior angles.

The differences which separate *Coenobita* from *Birgus* are small, but the following may be mentioned:—(i) The anterior tubercle of the lateral tooth is wanting in *Coenobita*. (ii) The hinder edge of the mesocardiac ossicle is rather more convex than in *Birgus*. (iii) The anterior edge of the cross-piece of the prepyloric ossicle is more concave. (iv) The calcified ring round the opening of the invagination on which the post-oesophageal brush is borne, articulates, in *Birgus*, with an elongated triangular strip in front of the pennate ossicle. (v) In *Birgus*, the cardiac disk and the arrangement of hairs on its lower edge are more developed than in *Coenobita*, and form the "suboesophageal valves" of Mocquard[3].

The *gastric musculature* shows no important difference from that of the Pagurids as figured and described by Mocquard. The strong gastric mill is provided with a correspondingly powerful set of muscles to work it. The *anterior gastric muscles* are a pair of stout strands inserted on the mesocardiac ossicle and diverging slightly as they run forward thence to their origin from the under side of a low, rounded, transverse ridge of the carapace, situated above the bases of the antennae and eye-stalks. This ridge is the "procephalic apophysis." The posterior gastric muscle of each side is divided into two bundles—an inner one, inserted on the thickened plate at the outer end of the pyloric ossicle, and an outer one, somewhat broader than the inner, inserted on the exopyloric ossicle. The origin of the inner bundle is partly from the anterior side of a thin, flat, triangular apophysis, which projects inwards and somewhat forwards from the cervical groove a short distance from the middle line, and partly from the carapace in front of this apophysis[4]. The outer bundle arises in front, and a little to the outside, of the other. The *cardiopyloric* or *superior cardiac muscles* consist on each side of three bands running backwards from the hind edge of the mesocardiac to be attached to the exopyloric ossicle. Of these three,

[1] For the facts on which the following paragraph is based I am indebted to Mocquard (*op. cit.*).

[2] The family Coenobitidae includes the genera *Coenobita* and *Birgus*.

[3] *Ann. Sci. Nat.*, (6), XIII. 3 (1883).

[4] Such an apophysis seems, from Mocquard's remarks on the gastric musculature of *Pagurus*, to be wanting in that genus. It is however present in *Eupagurus bernhardus*, where it is directed *forwards*.

that which is outermost at its origin from the mesocardiac ossicle passes under the middle one and is attached posteriorly between this latter and the inner band[1].

The cardiac disks are provided, as in the other Pagurinea, with *dilator muscles*, running forward to the cephalic wall. Mocquard[2], discussing the working of the gastric musculature of the Decapoda, concludes that the function of the dilators of the stomach[3] is, by enlarging its cavity, to draw into it fluids, carrying with them the solid particles of the food. On the relaxation of the dilators, the constrictors[4] of the stomach will drive out the liquid, while the solid matters will be caught on the filter provided by the hairs on the cardiac disks or elsewhere near the opening of the oesophagus. This theory is very plausible, but there are considerable difficulties in the way of its acceptance in the case of the genus *Coenobita* at least. For the great majority of the food is by these creatures eaten absolutely dry, with only such juices as it naturally contains. If, for instance, an individual be watched in the act of consuming one of its most common articles of food —the fruit of the *Pandanus*—it will be seen to hold the food firmly with the great chela, while the smaller one is employed in stripping off the fibres of the fruit and placing them between the maxillipeds of the third pair, which open to receive them, and then pass them on towards the mouth. They are not immediately rejected, and presumably are sent into the stomach after having undergone a first crushing by the mandibles. In any case the powerful gastric teeth argue a mastication of some part of the food there. Now the *Pandanus*-fibres, and indeed the majority of the food of all sorts, cannot be supposed to contain enough moisture to convey the solid part to the stomach, however much it may be broken up by the mandibles. And the fact that the stomach, when opened, contains but little fluid, precludes the suggestion that its watery contents, passing backward and forward, continually perform the same function of carrying solid food from the mouth to the stomach.

These considerations appear to conclusively negative Mocquard's theory of swallowing in the Decapods. For, although the same difficulty does not exist in marine forms, the similarity of the mechanism in the two cases makes it difficult to suppose that a different method is adopted in each. The subject is at all events worthy of further investigation. It may prove to be the case that the more liquid part of the food is swallowed in the way described by Mocquard (and suggested before him by Parker[5]) while the more solid portion is either rejected or swallowed by some other mechanism, as, for instance, by the constrictors of the oesophagus.

B. The Mid-gut[6]. (Pl. III. figs. F, G.) As in other Decapods, the stomach of *Coeno-*

[1] The mode of action of the gastric mill of Decapoda is discussed in Mocquard's paper and in Huxley's "Invertebrates." Briefly put, it is as follows:—The contraction of the anterior and posterior gastric muscles has the result of bringing the three teeth (median and lateral) together. On their relaxation the ossicles return to their normal position by the elasticity of the stomach-walls, and also partly by the action of the cardiopyloric muscles.

[2] Mocquard, *Ann. Sci. Nat.*, (7), XIII. 3, p. 3 and XVI. 1, p. 255.

[3] Of course the above-mentioned dilators attached to the cephalic disks, though they are the chief, are not the only ones. Setting aside the dilators of the oesophagus and those of the pyloric division, the following, attached on the cardiac half of the stomach, are described by Mocquard; the anterosuperior (on the cephalic disk), the anteroinferior, the anterior and the posterior lateral.

[4] Of these there is one on each side—a band of fibres inserted on the cardiac wall at the front end of the side-plate, and running downwards and a little forwards to the oesophagus.

[5] T. J. Parker, *Journ. Anat. Phys.* XI. p. 59 (1876).

[6] Bouvier, in a short article "Sur la Respiration et quelques dispositions organiques des Paguriens terrestres du Genre Cénobite" [*Bull. Soc. Philomath.*, Paris, (8) II. p. 194 (1839)], remarks briefly on this and other internal organs of *Coenobita*. His observations were made on *C. diogenes*, and it is interesting to find that, so far as they go, they support mine, which relate to the Indo-Pacific species.

bita is followed by the *mid-gut* or *mesenteron*—a short, soft-walled tube, which grows gradually narrower from before backwards in consequence of the difference in width between the pyloric division of the stomach and the hind-gut. Through the roof of the mid-gut there opens on each side a short, curved coecum of simple form with its blind end directed forwards. Through the floor open the two bile ducts.

The Liver (Pl. III. fig. F). The same compression of the thorax, which has affected the shape of the stomach, has brought about the displacement of the liver of the hermit-crabs backwards into the abdomen. Starting from the underside of the mid-gut, one close on each side of the middle line, the bile ducts may be traced backwards below the hind-gut, gradually diminishing in calibre all the way. On its outer side each duct bears, at almost regular intervals, about a dozen stout tubes or primary ductules, the first of which enters nearly at the level of the last thoracic leg. Each of these ductules curves upwards and inwards over the hind-gut, diminishing in diameter by giving off secondary ductules along its outer side. These in turn give off ductules of a third order, and the latter bear the terminal tubules of the system arranged in tufts. Each tuft opens by a short tube (ductule of the fourth order) on the outer side of the tertiary ductule. The terminal tubules are long and usually cylindrical, though some of them show bead-like swellings at intervals. The whole of the tubules borne on a secondary ductule form, in the natural position of the organs, a well-marked secondary lobule, and all the secondary lobules of a primary ductule form a primary lobule. These lobules, though they are placed at fairly regular intervals along the bile-duct, and roughly correspond on the two sides of the body, are not segmentally arranged in the abdomen. Moreover, owing partly to the fact that the primary ductules run, not straight upwards round the hind-gut, but also somewhat backwards, the lobules come to overlap one another on the dorsal side of the gut, and their arrangement appears at first less regular than it really is. Besides those arranged on the above system, each bile-duct bears, on its anterior portion, a certain number of tubules directly sessile upon it. These gradually diminish in size from behind forwards, till a short stretch of the bile-duct, just behind the opening, is left quite free from them. Hindwards the bile-duct begins by the junction of two primary ductules.

We may speak of the whole of the lobules of each side as forming a right and a left liver respectively. The left liver, then, is somewhat smaller than the right, though the difference is not very marked. At the hind end of the abdomen the left liver passes dorsal to the right. The whole of the structures just described are bound together by strands of connective tissue carrying blood vessels. This circumstance, combined with the soft, easily-breakable texture of the liver, makes that organ rather difficult to unravel.

C. The Hind-gut. (Pl. III. fig. G.) Behind the mid-gut, and stretching from it to the anal opening in a direct course, runs the chitin-lined hind-gut. Its width is even for the first three-fourths or so of its length and then it increases gradually to a greater diameter. There are no rectal coeca.

Outwardly, the surface of the hind-gut is smooth, but within it is thrown into ridges. These ridges, which are twelve in number, are most marked at the hind end, grow gradually lower forwards, and finally fade away in the middle of the first abdominal segment, some distance from the end of the mid-gut. They are not all of equal size, being alternately large and small, or rather high and low, for there is not much difference in breadth. Each bears

a series of small transverse ridges, and each of these is again made up of a row of four or five minute oval beads set with their long axes lengthways in the intestine, that is transversely to the ridge which each row of them composes. The whole of these structures are, of course, covered with a delicate chitinous pellicle. In the anterior region of the hind-gut, where the ridges are wanting, the inner surface is covered with similar small beads, less regular in shape, set in longitudinal rows. The transition from the mid- to the hind-gut is hardly visible outwardly in fresh specimens, but in a gut which has been for a few hours in spirit it is very easy to see, owing to the difference in calibre brought about by the shrinkage of the mid-gut. Internally, the beaded appearance of the hind-gut makes the distinction a sharp one. In the natural position of the organs in the body a great part of the hind-gut is hidden by the overlapping lobules of the liver, but more or less of the hinder part usually comes into sight amongst the lobules.

The *anus* (fig. 18) is situated on the under side of the telson. It is guarded by a strong valve in the form of an oval calcified convex plate (1, fig. 18), attached to the soft ventral wall of the telson in front of the anus, and projecting back under it. If this plate be parted from the body of the telson, the anus is seen as a longitudinal slit at the bottom of the hollow between it and the telson. Between these two structures, then, there is a sort of cloaca, into which the anus opens. The aperture of the cloaca is surrounded by a thick growth of hairs. The result of this arrangement is that the opening for the discharge of faeces is directed, not ventralwards, in which case it would be liable to be pressed against the columella of the shell and thus obstructed, but backwards, and is further protected from pressure by the stout plate beneath it. Possibly the object of the hairs round the opening is to prevent the entrance of faecal matter as the animal shifts in its shell, though it is remarkable that the shells of these voracious creatures contain quite a small quantity of dung. In the Galatheinea and Brachyura, groups whose members carry the abdomen pressed more or less strongly against the underside of the thorax, the same arrangement is found in a less complete form, the anus being usually prominent and directed more or less backwards.

(iii) **The vascular system** (fig. 19).

The rather large, muscular *heart* (19, fig. 19) lies, as usual in the thorax, close under the dorsal carapace behind the cervical groove, surrounded by the thin-walled pericardial sinus, in which it is suspended by the three pairs of fibrous *alae cordis*, and with which it communicates by the usual three pairs of ostia. In shape it appears roughly four-sided from above, the anterior end being drawn out into a low prominence from which arise the three anterior arteries. The hind end has also a low, rounded, median bulge. At about a third of its length from the hind end there is on each side a notch. The dorsal surface is slightly convex; the sides slope inwards to the ventral surface, which is flat, and is raised, at the hind end, into a round, median lobe, from which the sternal and abdominal arteries arise.

Arteries. Seven vessels are given off from the heart. At the front end there arises a group of three—a median *ophthalmic* and two lateral *antennaries*. A short distance behind these the paired *hepatics* are given off from the ventral surface of the heart; and at the hind end the ventral lobe bears two median arteries, a more anterior, ventrally directed *sternal*, and a more posterior, terminal *abdominal*.

The *ophthalmic artery* (1, fig. 19) runs straight forward over the roof of the stomach without giving off any branches, and finally divides into two vessels which diverge forwards at an acute angle, to supply the eyes. There is no swelling, or median prolongation beyond the bifurcation. The *antennary arteries* (2, fig. 19) run forwards and outwards from their origin on each side of the ophthalmic artery. On the inner side each gives rise to

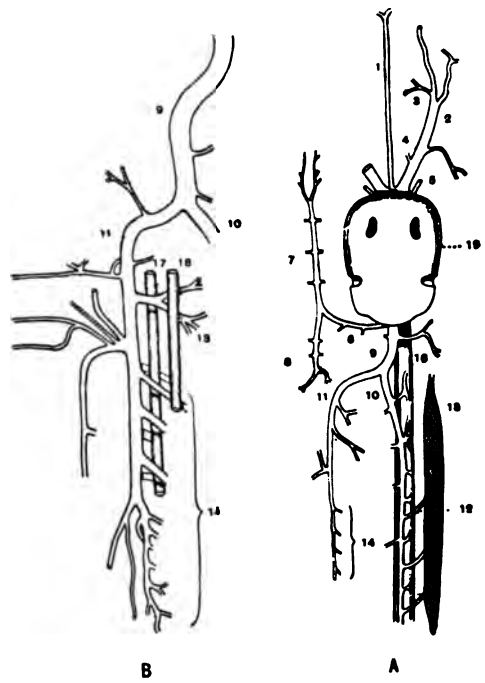


FIG. 19. Arterial system of *Coenobita clypeatus*. A. Arteries of female from above; B. Left or lower branch of abdominal artery of male (enlarged). 1. Ophthalmic. 2. Antennary. 3. Anterior gastric. 4. Posterior gastric. 5. Hepatic. 6. Sternal. 7. Ventral thoracic. 8. Ventral abdominal. 9. Dorsal abdominal. 10. Right branch of abdominal. 11. Left branch of abdominal. 12. Ovarian. 13. Spermatic. 14. Branches to liver. 15. Ovary. 16. Hind-gut. 17. Right bile duct. 18. Left bile duct. 19. Heart (represented too large).

an anterior and a posterior gastric artery, which supply the musculature of the stomach. At about the level of the anterior gastric artery there is given off on the outer side a stout branch, which runs downwards and forwards to the green gland. At a short distance in front of the posterior gastric artery a less important outer branch arises, to be distributed to the muscles of the adjoining part of the thorax. In front of the stomach the diminished artery is continued forwards to supply the antennae. Besides the above, there are other smaller and more variable branches.

The hepatic arteries (5, fig. 19). The position of the liver in the abdomen deprives these arteries of the function which gained them their name in other Decapods. It is perhaps best, however, to retain it, rather than add to an already overladen terminology. The hepatic arteries, then, in *Coenobita* do not supply the liver, but run downwards and forwards from the heart to supply the sides of the stomach. *The sternal artery* (6, fig. 19) on leaving the heart runs directly downwards, passes on one side or other of the intestine, and ends by going through the oval hole in the thoracic ganglion and dividing immediately underneath the latter into two branches, one of which passes directly forwards in the middle line and is known as the ventral thoracic artery, while the other runs directly backwards. This latter is the homologue of the ventral abdominal artery of other Decapoda. It has here very little right to the name, but to avoid confusion, and also because it does actually

send two small branches into the abdomen, may be allowed to retain it. The sternal artery, in its vertical course, that is before its bifurcation, gives off two or three small branches backwards towards the abdomen. The *ventral thoracic artery* (7, fig. 19) gives off branches right and left to the third, second and first pairs of legs and then bifurcates into two trunks, one for each side, which supply the mouth-limbs and send a branch to the green gland of each side. The *ventral abdominal artery* (8, fig. 19), in its course through the hinder part of the thorax gives off vessels to the last two legs and then, on arriving at the base of the abdomen, divides into two small branches, which ramify among the abdominal organs. In the possession of these two little vessels, and in the greater regularity of the arrangement of vessels to the limbs, the sternal arterial system of *Coenobita* differs from that of *Eupagurus* described by Bouvier[1].

The *abdominal artery* (9, fig. 19). For a short distance this great vessel runs a straight course backwards, giving off a few small twigs to the muscles of the hinder part of the thorax. But a little behind the junction of thorax and abdomen it divides into two branches. Of these one, the smaller (10, fig. 19), passes on in the middle line above the hind-gut, lessening as it goes by giving off small vessels to the gut and ovary. The larger of the two, however, turns downwards and then backwards again, and continues its course below the liver and above the broad band of muscle which represents, in the Pagurinea, the abdominal muscular system of other Decapods[2]. As it goes, this vessel gives off branches upwards to the liver and testis and downwards to the muscles. In particular one large branch, given off not long after it resumes the backward direction, supplies much of the muscle-band and even sends a branch forward into the thorax. Further back still, the main vessel divides into two. One division passes into the muscles, the other runs on dorsal to the muscle-band, continuing to supply it and the liver. The sub-muscular division reappears at the hind end of the abdomen and curves forward, breaking up and anastomosing with the other vessels of the liver.

Venous system. The arteries, after dividing into finer and finer branches, end by discharging their blood into the great venous sinuses in which all the organs of the body are bathed. The arrangement of these in *Coenobita* seems to be much the same as in other Decapods. In connection with the respiratory organs, however, certain peculiarities must be noticed. Roughly speaking, the blood from a sternal sinus passes to the gills and so to the pericardium, that from a gastric sinus to the branchiostegite and so to the pericardium, and that from an abdominal sinus to a plexus under the skin of the abdomen and thence by two veins on each side to the pericardium. Some further particulars will be found in the next section.

iv. **Respiratory Organs**. Respiration takes place in three distinct regions of the body of a *Coenobita*: (1) in the gills, (2) in the lining of the branchiostegite, (3) in the abdominal skin. It must, of course, be borne in mind that in this case the surrounding medium is not water, as with the great majority of Decapods, but air.

The gills are of the type known as "phyllobranch"; that is to say they consist of an axis bearing on each side a series of thin-walled plates through which the blood flows

[1] Bouvier, "Récherches anatomiques sur le Système Artériel des Crustacés Decapodes." *Ann. Sci. Nat.* (7), v. p. 197 (1891).

[2] See above, p. 69.

freely. The axis is attached at one point to the side of the thorax, and there the blood enters it. The lamellae diminish in size towards each end of the axis, whereby the whole gill becomes spindle-shaped. The gill-formula is as follows[1]:—

	Podobranch	Anterior arthrobranch	Posterior arthrobranch	Pleurobranch	Total
1st maxilliped ...	0	0	0	0	0
2nd „ ...	0	0	0	0	0
3rd „ ...	0	rud.	rud.	0	2 rud.
1st leg.....	0	rud.	rud.	0	2 rud.
2nd „	0	1	1	1	3
3rd „	0	1	1	1	3
4th „	0	1	1	1	3
5th „	0	0	0	1	1
Totals...	0	3+2 rud.	3+2 rud.	4	10+4 rud.

The arrangements for the supply of blood to the gills consist, as usual, of afferent branchial vessels, arising from the sternal sinus, and of efferent vessels leading to the pericardial sinus and so to the heart.

The lining of the branchiostegite is a thin, smooth membrane. There is no spongy tissue such as is found in *Ocypode* or vascular tufts as in *Birgus*. According to Bouvier[2], blood enters the branchiostegite from the large sinus which encloses the stomach, and leaves by the great vein, which may easily be found at the hinder edge of the organ. This starts in front as a small vessel and runs backward round the lower edge of the branchiostegite, enlarging as it goes. Finally it curves inwards with the hinder edge of the branchiostegite and, when this rejoins the body, passes on to the pericardium. I did not find it possible by injecting this vessel to irrigate any definite plexus in the branchiostegite. The coloured fluid passes with great readiness into the space between the strong outer and the delicate inner wall of the organ, but it is here contained in a loose and irregular system of lacunae, or rather in a single cavity divided by strands of tissue.

The gill chamber. Provision for moistening the gills. The third leg in its normal position, pressed up against the soft branchiostegite, indents the latter in such a way as to limit the branchial chamber to a comparatively small region in the hinder and upper parts of the thorax. This chamber is widely open behind, so that the gills can generally be partly seen without lifting the branchiostegite. The animal seems to be able to increase this opening at will, but over the greater part of their surface the branchiostegite lies fairly close above the gills. There is thus no attempt at the formation of anything like a lung. The free edge of the branchiostegite is incurved, and the trough thus formed is lined with hairs and usually very moist. Another hairy surface, possibly of importance in the retention of water, is to be found on the wall of the thorax above the gills, between them and the origin of the branchiostegite.

[1] The gill-formula of *Pagurus* is the same as that of *Coenobita* save that the gills on the third maxilliped and first leg are better developed. *Eupagurus* differs in having only one pleurobranch—that on the fourth leg.

[2] Bouvier, *C. Rend.* cx. pp. 1211 ff. (1890). My observations, which confirm those of Bouvier, were made when I was in ignorance of his researches on the blood supply of the branchiostegite.

The source of the moisture is a problem of some obscurity. It is of the very rarest occurrence for a *Coenobita* to be found in the water except at the breeding period[1]. Ortmann states quite distinctly that, out of many hundreds, he has never seen one in the water. Nor have I myself succeeded any better in this respect. That they do visit the sea, however, I am convinced by two facts. First, that Mr Stanley Gardiner had the good fortune to find a specimen of *C. perlatus* in the water a few feet from the lagoon beach in Minikoi. It is true that this was a female, but there were no eggs or young, nor any traces of them, on her abdominal limbs. Secondly, that the body of a freshly caught specimen is always moist, and in a great many cases (certainly the majority of *C. perlatus* and *C. rugosus*) the shell actually contains a small quantity of salt water[2].

Another possible method of moistening the gills must not be overlooked. In some experiments to test the effect of drying the gill chamber it soon became evident that this was an impossibility. By the careful use of cotton-wool and blotting-paper, a great part of the moisture could be removed, but absolutely dry it was quite impossible to make the chamber. After a time the limpid salt water became replaced by a more sticky fluid, which frothed with the violent efforts of the scaphognathite. Of course it is possible that this was blood, flowing from wounds in the delicate cuticle lining the chamber, made during the process of drying. But I was unable to detect any such wounds, and the same thing happened in each of several experiments. Another explanation of the phenomenon is that the fluid was provided by exudation through the lining of the chamber. No doubt in this case the exudation was abnormal in quantity and quality. But it served to indicate a possible method of keeping the gills moist. In support of this is the fact that specimens made approximately dry[3] with cotton-wool and then placed in a dry wooden box, lived, and remained in good health for weeks. No doubt, if the suggested process of exudation takes place, the different species of the genus are dependent on it to different extents. One would expect, for instance, that it would play a greater part in species such as *C. spinosus*, which often live at some distance from the sea, than in *C. rugosus*, which is generally to be found close to sea-water.

The movements of the scaphognathite. On raising the forepart of the branchiostegite of a *Coenobita* the plate on the second maxilla, to the movements of which the respiratory current in water-living Decapods is due, will nearly always either be found to be in motion or shortly begin to move. When the animal is placed in water, either fresh or salt, it is easy to show, by means of a little carmine or other coloured fluid, that the ordinary current is produced here also. It enters at the hind end of the branchial chamber and between the last two legs, passes over the gills and through the narrow passage which leads downwards and forwards from the upper part of the gill-chamber proper, and finally issues under the antenna. I have not been able to observe a reversal of the current, such as that described by Bohn[4] in many Decapods. The meaning of the movement of the scaphognathite when the animal is on land is not clear. It is possible that its object is, by acting as a fan, to create a draught of air through the gill chamber. In considering this view, however, we are met by the difficulty that there are often long pauses in the movements, and that removal of the scaphognathite has no perceptible effect on the animal.

[1] See below, p. 91.

[2] See below, p. 91.

[3] If the drying process be continued too long, it is apt to kill the animal.

[4] Bohn, *C. Rend.* cxxxv. p. 539.

It may be that the stimulus of lifting the branchiostegite is sufficient to set the appendage in motion, but in this case one would expect the movements either to cease directly or to continue as long as the branchiostegite is raised. This is not what happens, the movements being sometimes steady and sometimes fitful and irregular. A third explanation, and the one which at present seems the most probable, is that we have here an instance of a vestigial habit, retained after it has ceased to be of use to the animal. Lastly, if it could be shown that both sexes are in the habit of going into the water at frequent intervals, yet another solution of the question could be offered. For in that case it would be possible to suppose that the motion of the scaphognathite was retained on account of its being indispensable to the animal under water and at the same time, for some physiological reason, not susceptible to inhibition for long periods and thus perforce continued on land. But this view would require assumptions, which there is no justification for making.

Abdominal respiration. At the time of my sojourn in the Island of Minikoi, I was unaware of Bouvier's[1] researches on this point. My own observations were much less complete than his, but I can confirm his statements with regard to the various channels carrying blood back from the abdominal walls to the pericardium, at least as regards the dorsal pair, the ventral I failed to observe. While he paid considerable attention to the anatomical side of the question, Bouvier does not appear to have made any experiments to test his theories. It is interesting to observe that if the gills of both sides be cut off, leaving small stumps to avoid loss of blood (it would be better to ligature the gills in a future experiment), the animal is still capable of living. Indeed one, on which I performed this experiment, lived several days, and finally escaped from the vessel it was confined in. Taken in conjunction with the fact that the action of the scaphognathite may be suspended without harm to the animal, this fact seems to indicate that abdominal respiration is of considerable importance in *Coenobita*. It is further interesting to note that the soft skin of the abdomen is always damp. Possibly the object of the hairs and fleshy processes on the ventral surface of the abdomen is as much to retain water as to play any part in respiration by movement, as Bouvier suggests. It would certainly appear, from the elaborate precautions taken in various groups of land Decapoda to ensure the presence of moisture on the breathing organs, as though respiration were, in them at least, impossible except through a moist surface.

v. **Kidneys (green glands)** (Pl. III. fig. H).

The kidney of *Coenobita* is a large oval cushion, of a pale greenish colour in the living animal, placed in the head on each side of, and rather behind, the brain, and behind the base of the antennae. The surface of the cushion is not even, but raised into a number of irregular rounded lobes, except in the middle of the upper side, where a space is left smooth, and forms a depression amongst the lobes. The hilum of the gland is in front and on the outside. I am quite unable to distinguish, by injection or otherwise, any vesicle such as is found in nearly all other Decapods and is especially well developed in the Pagurids. The only other instances in which this does not occur are quoted by Marchal

[1] Bouvier, *Bull. Soc. Philomath.*, Paris (8), II. p. 194 (1890). Briefly put the apparatus consists of a tegumentary plexus, fed from the abdominal sinus and communicating with the pericardium on each side by two veins—a long dorsal and a short ventral one. The two veins of each side join before entering the pericardium.

Comparing these structures with the same parts in *Paguristes* and *Eupagurus*[1], the following points appear. The testis is more compact in *Coenobita* than in either of the Pagurid genera. In shape it represents, with its hinder swelling, a more definite form of the type foreshadowed by *Eupagurus*, which is, in this respect, intermediate between *Paguristes* and the land genus. On the other hand, in having one spiral section (instead of two, sundered by a straight tube), as also in the small calibre of this region, *Coenobita* approaches *Paguristes* rather than *Eupagurus*. But in the shortness of the very narrow tube which comes immediately before the spiral, that is which separates the spiral and the conducting tube proper, it again resembles *Eupagurus*. The *male opening* is in the usual position on the coxopodite of the fifth leg of each side. The portion of the joint which bears the opening is always more or less prominent and, in some cases (*C. rugosus*, *C. perlatus*) is, on the right side of the body, prolonged into a penis-like process. In *C. perlatus*, however, in which this feature is very marked, bringing about a complete dissimilarity between the openings of the two sides, there is no sign of degeneration in the left testis, and its duct may contain sperm. The first abdominal segment being, in both sexes, unprovided with appendages, there is here no copulatory organ of the type common in other Decapods.

B. *The female organs.* The *ovaries* are a pair of simple cylindrical structures lying in the abdomen one on each side of the median line close above the hind-gut along the middle portion of its course. In *C. clypeatus* the ovaries are separate. In *C. rugosus* and *C. perlatus* they join for a short distance at their hind ends[2]. The *oviduct* is a simple tube, arising from the anterior end of the ovary and running straight forwards to its small round opening on the ventral face of the coxopodite of the third leg.

C. *The relative numbers of the sexes* seem fairly equal, a collection taken at haphazard giving sometimes a small preponderance of one, sometimes of the other.

viii. **Reproduction.** Whether *Coenobita* have a definite breeding season or not, and, if so, when it occurs are questions that still remain to be settled. Certainly, females with eggs may be taken throughout the summer in Ceylon[3]. The copulation is another point deserving further investigation. Very little is known on this subject as regards most Decapods. *Paguristes* is said to insert a penial process into the vulva of the female[4], and possibly the same use is made of the "penis" of *C. perlatus*. That of *C. rugosus* is too broad for insertion, but is no doubt of use in placing the sperm in some required position. At the same time the reproductive organs of the left side of the body show every sign of being functional in these, as in the other species of the genus, and the problem is thus complicated by the probability that their sperm is deposited in a different way from that of the right side of the body.

The eggs are carried in large masses attached to the long hairs on the well-developed limbs on the right side of the second, third and fourth abdominal segments of the female. They are arranged irregularly along the hairs[5] and fixed, as in other Decapods, by an

[1] Grobben, "Beit. Kennt. Männ. Geschlechtsorg. Dekapoden," *Arb. Zool. Inst. Wien*, I. 2 (1878).

[2] In *Pagurus* they are said to remain separate.

[3] Mr Stanley Gardiner suggests to me that the south-west monsoon is the main breeding season in the Maldives. He was in these islands during the north-east monsoon, and found great difficulty in finding females with eggs at that season. The same is the case in Ceylon.

[4] Ortmann, Bronn's *Thierreich*, v. 2, p. 1075.

[5] In *Birgus* they are in clumps at intervals along the hair. Borradaile, Willey's "Zool. Results," Pt. v. p. 585 (1900), "On the Young of the Robber Crab."

outer shell, prolonged into a stalk which adheres to the hair. The ripe egg is ellipsoidal, and measures, when preserved in spirit, 7·5 mm. by 7 mm. in *C. perlatus*, and in *C. rugosus* rather less. It is thus a little smaller than that of *Birgus*[1]. In two species at least (*C. rugosus* and *C. perlatus*) the young are hatched as zoaea larvae[2] of a type much resembling those of other Pagurinea[3] and washed off into the sea. They are not swept out in the respiratory current in the manner described by Bate[4] for *Eupagurus* nor is it necessary for the female to issue from her shell, though she may do so if kept under water too long in a state of captivity. It is possible, though perhaps not very likely, that the habits of some of the other species, especially those which live at greater distances from the water, may have led to their young being hatched in a later stage[5], as is said to be the case with some land crabs[6]. A zoaea which seemed identical with that of *C. rugosus* was taken at night with the tow-net in the lagoon at Minikoi.

The embryonic skin, which encloses the Decapod zoaea before hatching, and is retained for a varying period in different forms, is here lost very shortly after leaving the egg. It is of simple form and much resembles that found by Sars in other Pagurine zoaeas, though I have not been able to discover any feathering on the processes of the glove-like structure which encloses the telson and its spines. The larva (fig. 21) is rather smaller than that of *Birgus*[7] (the length is, in *C. perlatus*, 3 mm. and in *C. rugosus* 2·5 mm., as against 3·5 mm. in *Birgus*), which it otherwise very closely resembles in all but a few points of detail. The *carapace* has a curved, pointed rostrum of moderate length. The hinder edge is hollowed, and at each side a rounded side-lobe replaces the spine usually found here. The *abdomen* consists of five segments and an end part, which shows indications of its coming division to form the sixth segment and telson[8]. The *telson* (*a*, fig. 21) has the usual fan shape with a rather deep median notch. On each side of the notch are five bristles, increasing in length from the first to the fourth, which is longer than the fifth. These bristles are feathered. The outer angle is provided with a stout tooth. None of the other abdominal segments are armed, save the fifth, which has a single strong spine on each side at the hind end. There are eight pairs of limbs, including a rudimentary pair of third maxillipeds. These limbs are almost exactly like those of the first zoaea stage of *Birgus*[9], except for the mandible (*b*, fig. 21), which has

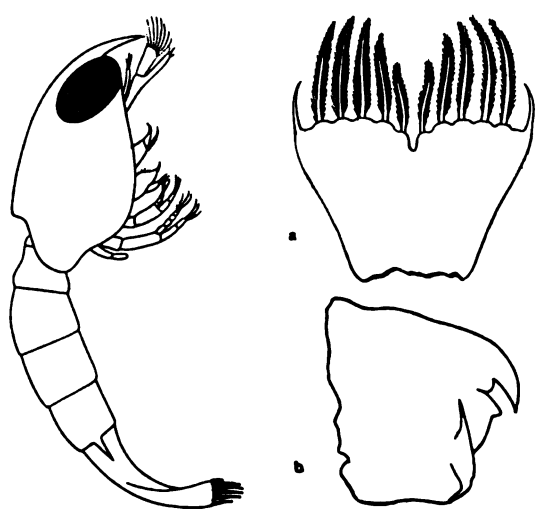


FIG. 21. Zoaea of *Coenobita perlatus*. *a*. Telson enlarged. *b*. Mandible enlarged.

[1] Borradaile, *loc. cit.*

[2] Borradaile, *P. Z. S.*, 1899, p. 937.

[3] G. O. Sars, *Arch. Math. og Naturvid.*, XIII. p. 133 (1839).

[4] Bate, quoted by Stebbing "Crustacea," p. 164, London, 1893.

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[7] Borradaile, Willey's "Zool. Results," *loc. cit.*

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In every respect the larva has a typical Pagurine organization, but resembles *Birgus* more nearly than the Pagurids. It differs from *Birgus* in: (1) its smaller size; (2) the arrangement of the bristles of the telson, which in *Birgus* are of nearly equal length; (3) the greater length and slenderness of the side spines of the fifth abdominal segment; (4) the greater simplicity of the mandible.

ix. **Notes on the habits**[1].

A circumstance which makes the habits of *Coenobita* somewhat more easy of investigation than those of other hermit-crabs, is that almost the whole of their life is spent on land. It has already been remarked[2] that the animals are rarely to be found in the water, but we must at the same time admit that this question is far from being disposed of. Their organization seems well adapted for a stay under water, and they may be proved experimentally, as we shall see, to have the power of living for some time in that medium, though it eventually proves fatal to them.

According to Hughes[3] *C. diogenes* is "often found cleaving to rocks in the sea" and "sometimes it is caught upon the rocks at a considerable distance from land." Again, in Minikoi, the shells of many examples of *C. rugosus* and *C. perlatus* contained considerable quantities of salt-water, and that in both sexes and irrespective of the carrying of eggs by the females. On the other hand Catesby[4] does not "remember to have seen any of them (*C. diogenes*) go into the sea," Ortmann[5] states that, out of hundreds of examples observed by him in East Africa, not one was found in the water, and, with a single exception[6], the same was the case in Minikoi. Moreover, in the case of species found at a considerable distance from the sea[7], frequent visits to salt water are out of the question. *C. rugosus*, *C. perlatus* and, according to statements[8], *C. diogenes* undoubtedly go down to the sea, when their young are hatching for the purpose of washing them off. Should they be proved to frequent the water at other times, it will be interesting to discover whether this be in connection with their breathing arrangements[9], or merely for some such purpose as obtaining a favourite food or escaping an enemy, and further whether it take place by night or by day[10].

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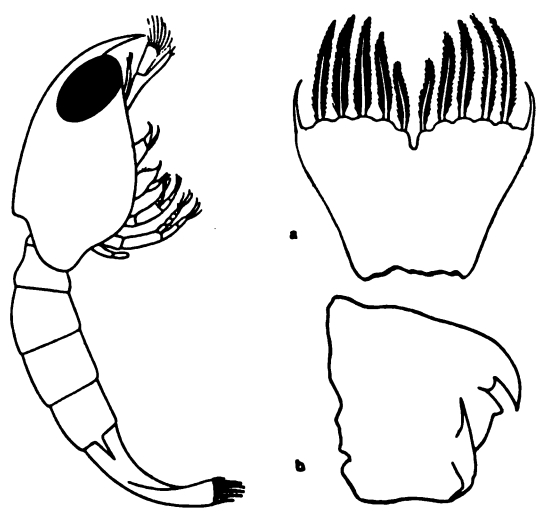

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other Decapods in being practically omnivorous[1]—belonging, in fact, to the class of scavengers. They pick up various dead sea-animals along the beach, and get other refuse elsewhere. On occasion, even cannibalism is not beyond them, when one of their number is wounded or killed. They are able to find their food in the dark, and there can be little doubt that this is due to a sense of smell, by which, rather than by sight, they are most likely guided in their search. Substances with a strong odour such as roasted coconut or the fruit of the *Pandanus* (which has a distinct and characteristic smell) are particularly attractive to them. It is interesting to watch the way in which a *Coenobita* will pause in its walk, unfold its long antennules[2] (see p. 70) and seem to explore the air with them, waving their flagella gently to and fro over its head. The same limbs are advanced and held over the food during feeding. They find the fruit of the *Pandanus* on the ground, but will also climb the bushes to reach it. On one occasion an individual was found in a *Hernandea peltata* about twenty feet from the ground, but its object in going there is hard to surmise. The curved end-joints of the legs can clasp tightly quite small twigs, and the sharp claws with which they are provided are, no doubt, of use in climbing. The food is often dragged for some distance, and in the case of fruits this is, no doubt, a method of distributing the seeds, which should be taken account of in considering the extension of vegetation over the land surface of a coral island.

In the matter of habitations, the choice is as varied as in that of food. Every available kind of land or sea gastropod shell is used, provided that it be of the right size and not so encumbered with spines as to be awkward in use. Weight seems to be of little account, the heavy *Turbo*-shells being especial favourites with *C. clypeatus*, although only comparatively small individuals can use them. One small specimen of *C. rugosus* in Ceylon was carrying the empty tube of a Serpulid worm. *C. spinosus* is known to use the nutshell of *Calophyllum inophyllum*[3], and *C. clypeatus*, when it has grown too large for gastropod shells, takes the half of a coconut[4]. A case even occurred in which a broken glass tube was made use of[5].

Ortmann[6] has pointed out the existence in *C. rugosus* (traces of the same structure are found in most *C. perlatus*) of an apparatus, which he regarded as adapted for producing a sound. This consists of a row of small ridges on the outside of the great (left) chela and a longitudinal ridge on the underside of the second walking leg of the same side. It is interesting to know that a number of these creatures shut up in a large tin

[1] Ortmann [Bronn's *Thierreich*, I. 2, p. 1234] seems to be of the opinion that *Coenobita* is purely vegetarian in its feeding, and quotes Dahl and Streets in support. But Catesby [*Nat. Hist. Carolinas*, II. p. 33] long ago observed that *C. diogenes* will occasionally take animal food.

[2] These appendages are, of course, those in which a sense resembling that of smell has been found to be located in other crustaceans. Lack of time unfortunately prevented me from making any experiments on this point, which I am sure would repay investigation in *Coenobita*.

[3] Borradaile, *P. Z. S.*, 1898, p. 459. Gastropod shells are probably scarce where this is done.

[4] In such cases as this, the means by which the creature retains its house are of interest. The abdomen is doubled forwards under the thorax, so as to present the roughened surfaces on the 6th abdominal limbs to the inside of the shell, and at the same time the 4th and 5th thoracic limbs make use of the similar patches on their propodites. Even so the hold on the shell is but a feeble one (see p. 72).

[5] A similar case is mentioned by Brock [quoted by Ortmann, Bronn's *Thierreich*, v. 2, p. 1216]. The interest of this observation lies in its bearing on the question of the means by which the animal recognises an object as being suitable for its "house." In this case it seems far more likely that the sense of touch was employed than that of sight. On the other hand, an individual removed from its shell, will make for another shell placed at some distance in a manner which seems to indicate that this is seen.

[6] Ortmann, Bronn's *Thierreich*, v. 2, p. 1249. Hilgendorf is said to have first called attention to the existence of this arrangement.

box, gave out continually a low, chirping sound, though it was not possible to discover how they did this[1]. The object of the sound is not clear, and theories on this subject must wait till the question of the hearing of the creatures is decided. They certainly often seem to be affected by sounds, but whether this may not be due to other vibrations started at the same time in the earth and surrounding objects is still doubtful to me, my information on the point being limited to desultory observations made at Minikoi before I was obliged to leave the island.

While they are not strictly nocturnal animals, the land hermit-crabs are certainly more active by night than by day. They seem to avoid the heat of the sun by preference, and to shelter, during the middle of the day, in nooks and crannies. Their habit of crowding together in any place, where food is to be found, makes them seem gregarious—which, in a strict sense of the word they probably are not. At the same time they may sometimes be found collected in considerable numbers for no apparent cause.

They are not given to fighting to the same extent as the hermit-crabs of the sea. When molested they withdraw quickly into their shells, closing the opening with the big left chela, which is specially adapted for this purpose. In this condition a *Coenobita* in a strong shell, such as that of *Turbo argyrostomus* must be an exceedingly tough nut for most animals to crack, and can also fall from a considerable height without injury. If they are unable to withdraw into their shells they will sometimes endeavour to defend themselves with the same powerful limb that is used to close the shell, but it often requires a considerable amount of teasing to induce them to do this. The grip of the great chela is exceedingly strong and will easily snap a twig which the animal has been made to seize.

If an individual be placed on its back, that is with the mouth of the shell uppermost, it will thrust out its body till the shell overbalances and the animal is able to recover the normal position. In moving, they crawl obliquely forward and to the left. From the accounts of eye-witnesses[2], it would seem that *C. diogenes* is considerably swifter than the Indo-Pacific species.

A series of experiments carried out with the object of investigating the vitality of the animals in fresh and salt water led to the following conclusions:—

(i) Continuous submersion under water is always fatal after a more or less prolonged period. (ii) There is great individual variation in the length of this period, but the sexes do not differ greatly[3]. (iii) The creatures are very sensitive to the effects of overcrowding. (iv) Tinned vessels are more injurious than enamelled ones. (v) There is a difference between the powers of resistance to fresh and salt water in favour of the latter, but the difference is not so great as might have been expected. The greatest length of life in salt water reached by any individual during the experiments was 6 days, but this was exceptional. In fresh water 24 hours was not exceeded. (vi) Of the three species, *C. perlatus* showed the greatest vitality in water and *C. clypeatus* the least, but the number of individuals of the latter experimented with was small. (vii) Before death the animal generally, but not invariably, comes out of

[1] Broderip [*Zool. Journ.*, IV. p. 205] quoting from the old "Encyclopédie" (Paris, 1751) states that *C. diogenes* makes a small sound when it is seized.

[2] Sloane, *Nat. Hist. Jamaica*, II. p. 272; Catesby, *Nat. Hist. Carolinas*, II. p. 33.

[3] Females with eggs do not differ from others in this respect, and the hatching larvae died almost as soon in salt as in fresh water. Had it been possible to rig up a "dipper," no doubt some of these might have been reared.

its shell. (viii) An individual, seemingly dead, may often be revived by being placed in the air, just as a marine crab, dying from exposure to the air, will come to life in water[1].

Some 200 specimens, mostly of the species *C. rugosus* and *C. perlatus*, were experimented with. The fresh water used was rain gathered in a "galvanised" iron tank. Owing to the limited number of vessels available and lack of time, the experiments were not as complete as they should have been. Still, they may perhaps serve to induce some more fortunately situated observer to carry on the enquiry. To obtain good results, each individual should be placed by itself in a vessel with a considerable quantity of water, which should be frequently changed. It would be interesting to try and induce the animals to feed under water. The few attempts, which I made at this, were unsuccessful. That death is not due to starvation is, however, certain from a consideration of the fact that they will live for weeks without food, if not placed under water.

3. Some notes on the land crabs of the genus *Ocypode*.

i. *Ocypode ceratophthalma* (Pallas).

This species lives in burrows in the sandy strand of the lagoon. Large warrens of these burrows extend along the shore just below extreme high-water mark. They are thus covered and destroyed at high tide, but during many hours are completely exposed. The mouth of the burrow is not always situated so as to be covered by an average tide, but the lower part always falls in at high water, owing to the loosening of the sand. The crab, which awaits this event at the bottom of its hole, is thus buried for some hours. When the tide falls it works its way out and repairs its burrow, and until the water returns may be seen moving about the shore near the opening[2], and running with extraordinary swiftness when threatened with capture. Under these circumstances the first impulse of the animal is to make for its hole, but, if cut off from this, it will seek safety in the water. The crabs double readily, and a favourite device with them is to remain still till the pursuer approaches and then suddenly dart off. These manœuvres are carried out on the tips of their slender legs and with the eyestalks raised so as to survey as wide a field as possible, and give the impression that the animals possess intelligence of a high order. When finally seized, they make vigorous efforts to defend themselves with their chelae.

As might be supposed from their burrows being submerged at high tide, and from their readiness to take refuge in the sea, the crabs are able to endure immersion in salt water for a number of hours, though they are eventually killed by it. Fresh water, on the other hand, is rapidly fatal, two hours being the longest period that any of them survived an experiment.

The burrows are inhabited each by a single crab, and Major Alcock[3] has shown that the stridulating apparatus, possessed by this species in common with most others of the

[1] In this connection it is interesting to note that the heart of the common hermit-crab [*Eupagurus bernhardus* (Linn.)] and the shore crab [*Carcinides moenas* (Penn.)] may often be found to be beating some time after every outward sign of life is lost from exposure to the air. Even when it has stopped, it may sometimes be induced by mechanical stimulation to give a few beats.

[2] In the hottest part of the day, when the sun shines full upon the beach, they are less active than at other times.

[3] Alcock, *Ann. Mag. N. H.* (6), x. (1892). For *O. ceratophthalma* see Anderson, *Journ. As. Soc. Bengal*, LV. (1894).

genus, is used, in *O. macrocera* at least, to warn out intruders. They differ somewhat in construction with the age of the inhabitant. The full-grown crab, of the sage-green and yellow coloration, makes a hole two or three feet deep with a spiral inclination of about one and a half turns either to the right or to the left indifferently. The burrow grows smaller from above downwards and, in the largest examples, has at the top a sort of vaulted chamber excavated in the sloping beach and leading downwards on one side into the spiral. In this chamber the crab may sometimes be seen sitting. The younger individuals, of a paler, whitish tint and with undeveloped horns on the eyestalks[1], make tubular holes at right angles to the surface of the sand and usually curving to one side or the other at the bottom—the beginning, perhaps, of the spiral of older individuals. There is often a small second opening to these burrows, which thus become roughly U-shaped. When an attempt is made to dig out the crab, it escapes by the smaller opening if one be present. If not, it makes a bolt to get out past the intruder. The larger individuals usually prefer to retire to the bottom of the hole and fight it out.

In digging its burrow, the crab brings up armfuls of sand between the chelae and the body, and throws it away at some little distance from the opening, thus making a low mound, and of course burying any object that may have been there. This process being repeated twice a day by a large number of crabs, a very considerable amount of sand is thus turned over[2], and the burrowing of these creatures must tend in the long run to the same end as that of earthworms—namely to the gradual sinking of any object originally lying on the surface to the level of the bottom of the burrows. That this really happens is shown by the fact that, in digging through the sand, one comes across objects that must have originally lain on the surface, and are now sunk to varying depths. This is the case not only with coral stones but with leaves, sticks, etc., often fresh and of recent burying at a considerable depth. In this connection it must, of course, be borne in mind that the food of the crabs consists largely of leaves and seaweed, which they are in the habit of carrying with them into their burrows[3]. They do not, however, do this with sticks, and a large mass of mammalian dung, found intact at a depth of about a foot in the sand, points to the same conclusion as the sticks. The larger holes reach a layer of coral pebbles interspersed in places with twigs, but in one locality Mr Stanley Gardiner found a mass of decaying vegetable matter containing earthworms. This probably consisted largely of material carried by the crabs to the bottom of their burrows for food.

It is possible that, in addition to their vegetable food, these crabs may be in the habit of catching and eating sandhoppers in the same way as *C. arenaria* (Catesby)[4]. I have not been able to see them do this, but some small individuals, shut up in a bottle with some sandhoppers and a little sand, caused the Amphipods to disappear in the course

[1] These horns, from which the species takes its name, are, of course, well known to be of very variable length in the adult.

[2] I am indebted to Mr Stanley Gardiner for the following figures, which he very kindly obtained for me after my leaving the Island. "Observations in 14 places between Lighthouse and west end of island. Lagoon shore. In areas of 5 sq. yds., greatest number 28 holes; least 2; average 14—15; sand thrown out twice in 25 hrs. Weight of sand from 12 large holes 19 lbs. 3 ozs.; average weight 9—10 ozs. Positions selected quite at random, at too great a distance to allow me to see whether they contained any holes or not."

[3] One or two leaves or pieces of seaweed may often be found in the burrows, but I have never come across anything like a lining of these materials. The destruction of the burrows by the tide would probably prevent this.

[4] S. I. Smith, cited by Stebbing, "Crustacea," p. 86, London, 1893.

of a few hours. The Ocypodes appear to find their food by sight, rather than by smell like *Coenobita*.

ii. *Ocypode cordimana*, Desm.

While it is alive, this crab is easily distinguished from *O. ceratophthalma* by its darker and more brownish colour, but when preserved in spirit it takes on much the same dull greyish-green hue as the other species. The two are, however, always quite easily separated by the absence, from *O. cordimana*, of the stridulating apparatus found in *O. ceratophthalma* as in all the rest of the genus. Their habits are also considerably different. Unlike the strand-haunting *ceratophthalma*, *cordimana* lives inland, digging its burrows in the light sandy soil along the paths and open spaces of the island. Instead of being directed downwards, these burrows usually take the form of more or less horizontal galleries with two, or sometimes three, openings. I have not found leaves, seaweed or food of any sort in those that I have opened, but they run among the roots of the vegetation and these may perhaps serve for food.

Two points of interest are raised by the facts just mentioned. In the first place it is worth remarking that the darker colour of *O. cordimana* harmonises better with that of its earthy environment than would the sandy hues of *O. ceratophthalma*. In the second, the existence of a species whose burrows are situated on land, well above the tide-mark, invalidates the conclusions, as to the raising of the land in Diego Garcia, drawn by Bourne[1] from the presence of Ocypod-holes in certain situations there. The form of these holes would have to be carefully investigated before any such conclusions could be drawn from them.

III. A list of land and fresh water Crustaceans collected in the Maldive Islands.

I am indebted to Mr Stanley Gardiner for the notes incorporated in the following list.

BRACHYURA, CATOMETOPA.

Family **Ocypodidae**. Genus *Ocypode*, Fabr., 1798.

1. *Ocypode ceratophthalma* (Pallas), 1772.

For references, see above, p. 67.
Generally distributed throughout the group.

2. *Ocypode cordimana* Desm., 1825.

For references see above, p. 67.
All the larger islands of the group except in Suvadiva and Addu atolls.

Genus *Uca*, Leach, 1815.

3. *Uca annulipes* (H. M.-Edw.), 1837.

Gelasimus annulipes, H. M.-Edwards. Crust. II. p. 55, pl. XVIII. figs. 10—13 (1837); Alcock, As. Soc. Bengal LXIX. ii. 3, p. 353 (1900) [references].
Uca annulipes, Ortmann, Zool. Jahrb. Syst. X. p. 355 (1897).
Mangrove Swamp, Furnardu, Miladumadulu atoll.

[1] Bourne, *P. R. S.*, vol. 43, p. 445 (1888).

Family **Grapsidae.** Genus *Geograpsus*, Stimps., 1858.

4. *Geograpsus grayi* (H. M.-Edw.), 1853.

For references see above, p. 67.
In every inhabited island of the group.

Genus *Metasesarma*, H. M.-Edw., 1853.

5. *Metasesarma rousseauxi* H. M.-Edw., 1853.

For references see above, p. 68.
General distribution throughout the group in damp land, especially at dry edges of mangrove swamps. Not found in Addu atoll.

Family **Geocarcinidae.** Genus *Cardiosoma*, Latr., 1825.

6. *Cardiosoma carnifex* (Hbst) 1794.

Cancer carnifex, Herbst, "Krabben" II. v. p. 263, Pl. XLI. figs. 1, 2 (1794).
Cardiosoma carnifex, Alcock, As. Soc. Bengal, LXIX. ii. 3, p. 445 (1900) [references].

Of general distribution throughout the northern atolls. Especially common in Miladumadulu and Mahlos. Generally makes its burrows under coconut trees at the edges of *kuli* or swamps, the openings being often covered at high tide. Not found in Addu atoll.

ANOMALA, PAGURINEA.

Family **Coenobitidae.** Genus *Coenobita*, Latr., 1826.

The distribution of this genus in the Maldives is somewhat peculiar. In nearly every island one species at least is found, but it is rare to find three. Two are frequently met with in the same island, and *C. rugosus* is the most common. In Goidu all four are met with, and Hulule, Male, has *perlatus*, *rugosus* aud *clypeatus*.

7. *Coenobita perlatus* H. M.-Edw., 1837.

For references see above, p. 68.
Of general distribution throughout the group.

8. *Coenobita rugosus* H. M.-Edw., 1837.

For references see above, p. 68.
Of general distribution throughout the group.

9. *Coenobita compressus.* Guérin, 1830.

Coenobita compressa Guérin, Voy. "Coquille," II. 2, p. 29 (1830).
Coenobita compressus, Ortmann, Zool. Jahrb. Syst. VI. p. 318 (1892) [references].
Goidu, and probably elsewhere.

10. *Coenobita clypeatus* Latr., 1826.

For references see above, p. 68.
Of general distribution throughout the group.

CARIDEA.

Family **Palaemonidae**. Genus *Leander*, Desm.

11. *Leander debilis* (Dana), 1852.

Palaeman debilis, Dana, U.S. Expl. Expd., Crust. I. p. 585, Pl. XXXVIII. figs. 6, 7 (1852).
Leander debilis, Ortmann, Zool. Jahrb. v. Syst. p. 515 (1890) in part.

Ortmann (*loc. cit.*) included under this species, as varieties, several other Leanders described by various authors. Among these was *L. longicarpus*, Stimps, 1860, which has since been identified by de Man and Coutière with *L. concinnus* Dana, 1852. The present collection contains examples of a form allied both to *L. debilis* and to *L. concinnus*, though more closely to the former than to the latter. In fact the points of difference between the preserved specimens would certainly be sufficiently small to justify their inclusion in a single species were it not that they exhibit considerable differences in colour and habitat. For notes on these I am indebted to Mr Gardiner.

The present species has 6—9 teeth on the underside of the rostrum and 4—6 above, and the carpopodite of the second leg just reaches the end of the antennal scale. Its size is rather greater than that of *L. gardineri*. When alive it is colourless, but has eggs of a brilliant dark green.

The only locality in which it was found in the Maldives was a kuli surrounded by a mangrove swamp in Landu, Miladumadulu atoll. It was here few in numbers and solitary in its habits.

12. *Leander gardineri*, n. sp.

Under the rostrum of this species are 4—6 teeth, and above it 5—6. The second leg of full grown individuals is longer than in *L. debilis* and its carpopodite exceeds the antennal scale. The size is less than that of *L. debilis*, the largest specimen being 33 mm. in length. The third flagellum of the antennule resembles that of *L. debilis*, and not *L. concinnus*, in being free for less than half its length. The colour is intermediate between straw and brown, the eggs being of a darker shade of the same; the branchiostegites a silvery-white.

This prawn was found in enormous numbers at the edges of a large fresh-water kuli in Ekasdu, Miladumadulu atoll. Both it and the former species are thus of interest in that, contrary to the usual habits of the genus, they live in fresh water. The allied *L. concinnus* lives indifferently in fresh, brackish or salt water.

ISOPODA, ONISCOIDEA.

Family **Ligiidae**. Genus *Ligia*, Fabr., 1798.

13. *Ligia exotica* Roux, 1828.

Ligia exotica, Roux, Crust. Médit. III. Pl. XIII. fig. 3 (1828).

Fairly common throughout the group on boats, ships, wharves, etc. At Mahugudu, Miladumadulu atoll, extremely common all round the shores of the island on the rocks. The specimens from the latter locality are somewhat smaller than those from other places in the group or than those met with in Ceylon or Minikoi, and their colour is different, consisting of a white ground covered with microscopic dark spots, giving a greyish appear-

ance unlike the uniform dark green of typical specimens. Possibly this is due to a state of contraction of the chromatophores at the time of capture. It may be, however, that we have here a local variety of the species.

Family **Oniscidae**. Genus *Porcellio*, Latr., 1802.

14. *Porcellio maldivensis*, n. sp. (fig. 22).

Definition:—A *Porcellio* with the body oblong-oval, rather more than twice as long as broad, not very convex, covered with large granules; lateral lobes of front moderate, rounded, anterior border of the same not much produced in the middle; hinder edge of first free thoracic segment curved forwards at the sides, that of the second less so, that of the third transverse; on the fourth a backward trend appears and grows increasingly strong till the seventh is reached; hinder angles of first three segments rounded, of fourth rectangular, of fifth to seventh acute; antennae rather more than half the length of the body, the two joints of the flagella equal; epimera of third, fourth and fifth abdominal segments of moderate size, very acute; somewhat adpressed; anal ring long, narrow, very acute, projecting well beyond the epimera of the fifth abdominal segment.

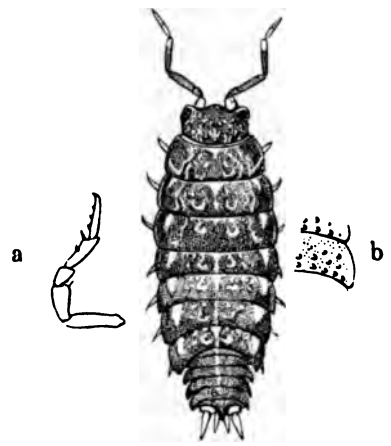


FIG. 22. *Porcellio maldivensis* (×8). *a*. Leg enlarged. *b*. Portion of segment enlarged to show sculpture.

Colour in spirit: brown mottled with yellowish; legs yellowish.

Length of longest specimen 6 mm.

This species seems somewhat transitional to *Metoponorthus*.

Mafaro, Miladumadulu atoll, under damp leaves.

Genus *Alloniscus*, Dana, 1854.

15. *Alloniscus maldivensis*, n. sp. (fig. 23).

Diagnosis:—An *Alloniscus* with the body oval and convex; the antennae not quite half the length of the body, the first two joints of the flagellum subequal, the third somewhat longer; the hinder margin of the first trunk segment curved forwards, those of the second and third transverse, that of the fourth slightly recurved at the sides, that of the fifth more strongly so, those of the sixth and seventh bent backwards sharply at an obtuse angle; the epimera of the third, fourth and fifth abdominal segments moderately large, acute and subequal; the end segment nearly twice as broad as long, triangular, acute, its sides slightly concave.

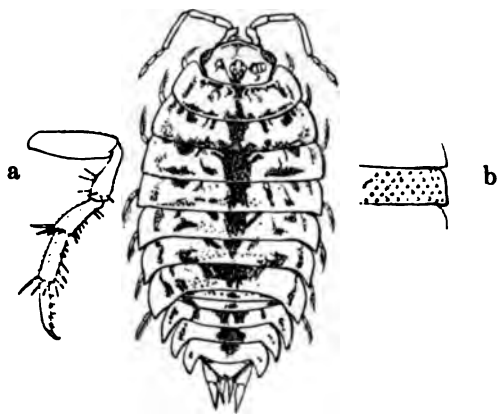


FIG. 23. *Alloniscus maldivensis* (×6). *a*. Leg enlarged. *b*. Portion of segment enlarged to show sculpture.

Colour in spirit: yellow marbled with black. Legs yellow with a few black spots.

Length of longest specimen: 3·5 mm.

Hedufuri, Mahlos atoll, under stones at edge of well.

Genus *Philoscia*, Latr. 1803.

16. ? *Philoscia gracilis*, Budde-Lund, 1879, var.

The collection contains specimens of a *Philoscia* taken in several different localities, but unfortunately all more or less damaged. They are at all events allied to *P. gracilis* (Budde-Lund Prosp. 2, 1879, and Isop. Terrest, p. 220, 1885), but differ from the description given by the author of that species in the following points:

1. The inner ramus of the uropod, though well-developed, is shorter than the outer.
2. The fifth trunk segment is no darker in colour than the rest.

Common in damp vegetable matter throughout the group, from Mahlos to Addu atoll.

17. *Philoscia*, sp.

Damaged specimens of a *Philoscia* from Hedufuri, Mahlos atoll.

Family **Armadillidiidae**. Genus *Cubaris*, Brandt, 1833.

18. *Cubaris murinus*, Brandt, 1833.

For references see above, p. 68.

Addu and probably also other atolls.

With the exception of the new species, all the above crustaceans are Indo-Pacific in distribution. The only feature of interest in this respect exhibited by the collection is the absence from Addu of several species found in the more northern atolls.

NEMERTEANS.

By R. C. PUNNETT, B.A. (Cantab.).

With Plates IV. and V.

To judge from our previous knowledge of the Nemerteans of the Indian and Eastern Pacific Oceans, the collection of these worms made by Mr Stanley Gardiner is, on the whole, much what one would have been led to expect. The genera *Eupolia* and *Drepanophorus* are well represented, as also is the family of the Lineidae. The curious genus *Prosadenoporus*, first met with at Amboina, is recorded for the second time only. The collection also includes examples of two of the most widely distributed Nemerteans in this part of the world, *i.e. Eupolia hemprichi*, and *Lineus albovittatus*. The collection is however noteworthy in that it adds to the fauna of these seas the first Mesonemertean recorded. *Cephalothrix aliena* belongs to a genus, which has hitherto been recorded from the North Atlantic and from the North-west Pacific[1] only. It is however not unlikely that, as the Nemertean fauna of the various regions of the globe becomes better known, this genus may turn out to be almost cosmopolitan. Almost all the species are excellently preserved, and I would take this opportunity of thanking Mr Gardiner for the energy and trouble expended in forming this collection. In the following pages a brief diagnosis of each new form is given, and this is followed by a more complete description. At the end of the paper I have appended a brief synopsis of the genus *Drepanophorus*.

SYSTEMATIC LIST.

I. Protonemertini[2]. (None.)

II. Mesonemertini.

Fam. **Cephalothricidae.**

1. *Cephalothrix aliena*, n. sp. Comparatively short, stout form with thick epithelium and basement membrane. Mouth beneath brain. No eyes. . . . p. 102

[1] Coe, W. R., *Proc. Wash. Acad. Sc.*, 1901, p. 19.

[2] The classification is that given by Bürger, *Naples Monograph*, 1895.

III. HETERONEMERTINI.

Fam. **Eupolidae.**

2. *Eupolia hemprichi.* (Ehrenberg, 1831.) . . . . . p. 104
3. *Eupolia indica,* n. sp. Externally marked by a single median dorsal and ventral brown line. Head much flattened. Circular head furrow marked by small longitudinal grooves inside. Excretory system connected with oesophagus . p. 104
4. *Eupolia unistriata,* n. sp. With single median black line. Greatly resembles *E. melanogramma* as regards internal structure . . . . . p. 106

Fam. **Lineidae.**

5. *Cerebratulus maldivensis,* n. sp. Small and somewhat flattened. Cutis feeble. Vascular head loop. Head slits reach past cerebral organ. No eyes. Frontal organ present. Excretory system short and with one pair of ducts . . . . . p. 106
6. *Cerebratulus maculatus,* n. sp. Medium sized and somewhat flattened. Covered with black pigment spots. Cutis weak. Vascular head loop. Head slits not past cerebral organ. Eyes. No frontal organ. Excretory system much attenuated and with one pair of ducts . . . . . p. 107
7. *Cerebratulus gardineri,* n. sp. Medium sized and somewhat flattened. Cutis feeble. Vascular head loop. Head slits prolonged just past cerebral organ. Eyes. Frontal organ present. Excretory system with one pair of ducts (occasionally more) p. 108
8. *Cerebratulus ischurus,* n. sp. Large and powerfully built form. Cutis feeble. Vascular lacunar network in snout. Head slits end abruptly where ciliated canal comes off. No eyes. Small frontal organ . . . . . p. 110
9. *Lineus albovittatus.* Bürger, 1890 . . . . . p. 111

IV. METANEMERTINI.

Fam. **Amphiporidae.**

10. *Prosadenoporus buergeri,* n. sp. No external markings. Head glands just past brain. Cerebral organ small and with ventral opening. Blind gut with two pockets only. 19 proboscis nerves . . . . . p. 111
11. *Drepanophorus roseus,* n. sp. Much flattened. Cerebral organ has lateral opening. It does not extend behind brain. Eyes very numerous. Proboscis nerves 22 . . . . . p. 112
12. *Drepanophorus cerinus* (Bürger, 1890) . . . . . p. 113

ACCOUNT OF THE SPECIES.

1. *Cephalothrix aliena,* n. sp. (Pl. IV. figs. 15, 16.)

Represented by 5 cc. of fragments about 1·5 mm. in breadth. Colour dirty white. Ant. end rounded and much contracted. No external markings to be distinguished. Posterior portion missing.

Locality. Felidu atoll, Maldive Is. Dredged from 20 fathoms.

The epithelium is, for this genus, very high (Pl. IV. fig. 15) and is marked by two rows of nuclei—one near the base of the epithelium and one about the middle. In the outer portion of the epithelium occur a few rhabdite-like structures which take a bright yellow hue with picric acid. This epithelium rests upon a thick basement membrane which is more than half the thickness of the epithelium itself.

A delicate circular muscle layer lies just beneath the basement membrane and is less than half the thickness of this latter structure. A thicker longitudinal muscle layer lies beneath the circular layer. Beneath this layer again there is in the oesophageal region an inner very delicate layer of circular muscles (Pl. IV. fig. 16 *mci*), which is well marked on the ventral surface of the oesophagus, and which is continued laterally to enclose the two lateral blood vessels. On the dorsal surface of these the fibres end. Between the proboscis sheath and the alimentary canal there is a delicate layer of longitudinal muscles both in the oesophageal and the intestinal regions.

The vascular system is extremely simple as in the other members of the genus. There are two longitudinal lateral vessels which unite together over the rhynchodaeum anteriorly. In the oesophageal region these vessels are exceedingly spacious. They are lined by a delicate flattened endothelium. They do not extend to the proboscis sheath.

The mouth is situated on the ventral surface directly beneath the brain. Its hinder termination is at a level slightly in front of the hind end of the brain. The oesophagus is short and passes directly into the intestine, which can be readily distinguished by the absence of gland cells in its epithelium. It possesses small lateral diverticula.

The proboscis is exceedingly fine, not exceeding ·16 mm. in diameter. It possesses a longitudinal muscle layer and an exceedingly delicate circular muscle layer just beneath the proboscis epithelium. The proboscis sheath possesses an extremely fine inner longitudinal and a somewhat thicker outer circular muscle layer. The rhynchocoelom is small.

There is no trace of nephridia.

The nervous system is poorly developed. The brain is small and the ventral ganglion is as large as the dorsal. The ventral commissure is fairly stout—the dorsal commissure is weak. Through the nervous ring thus formed pass proboscis sheath and blood vessels. The oesophageal nerves are well marked. A well marked median dorsal nerve is present between the basement membrane and circular muscle layer. There is also between these two layers of the body wall what appears to be an exceedingly delicate layer of nerve fibrils, and minute twigs may be observed piercing the basement membrane to reach the epithelium above.

There are no special sense organs, frontal organ, eyes, and cerebral organ being all absent. Moreover there are no traces of cephalic slits. There are no head glands.

The single individual procured is a female and the ovaries extend into the hinder oesophageal region. They lie rather dorsal to the level of the nervous side stems (Pl. IV. fig. 16), and to the outer side of the blood vessels into which they project. The cavity of the ovary is only separated from that of the vascular system by the delicate endothelium of the latter. No gonidial ducts are developed. The ova are apparently not yet mature.

The most marked point of difference between *C. aliena* and the rest of the genus lies in the relative positions of mouth and brain. In all the other species whose anatomy has been described the mouth lies behind the brain, and usually some distance behind. The structure of the epithelium with its double layer of nuclei is more complex than in the rest of the genus. In the presence of an inner circular muscle layer *C. aliena* resembles *C. signata* and differs from the other species of *Cephalothrix*. The great thickness of the basement membrane also is unusual. Moreover to judge by the figures in Bürger's Monograph (Taf. II.) the rhynchocoelom is less spacious and the blood vessels considerably more so than is usually the case.

2. *Eupolia hemprichi* (Ehrenberg, 1831). (Pl. IV. figs. 2, 3.)

Syn. *Nemertes hemprichi*, Ehrenberg, Symbolae Physicae, 1831.
Eupolia brocki, Bürger, Zeit. f. wiss. Zool., 1890.
Eupolia hemprichi, Bürger, Naples Monograph, 1895.
Eupolia hemprichi, Punnett, Willey's Zool. Results, Pt. v., 1900.

Locality. Found sparsely on every reef.

Several specimens of this common and widely-distributed species were obtained from the reefs both in the Maldive and the Laccadive Islands.

The size after preservation varied from 6·5 cm. to 104 cm. in length. The last-mentioned specimen is larger than any other yet recorded. The following note was made on the living worm by Mr Stanley Gardiner: "Length when obtained out of a hole in the rock of the reef-flat 5 ft. 6 in. (= 167·6 cm.). Black streak down centre of back and same transverse behind head." These markings become brown after preservation. There was in this specimen also a pigment fleck on the tip of the head and further a ventral line of about the same width as the dorsal extending along the whole length to the collar just behind the mouth. Here, however, it is much thinned (Pl. IV. fig. 2), and the collar is also incomplete ventrally. In markings as well as in size this specimen is intermediate between the figures which Bürger gives of *E. brocki* (*loc. cit.* 1890, Taf. I. fig. 10) and of *E. mediolineata* (Zool. Jahr. Bd. 7, Abt. f. Syst. Taf. VIII. fig. 1). The thickness of the dorsal and ventral lines and also of the transverse one is exceedingly variable. In one case the line may be at least one-third of the body-width, whilst in another it is exceedingly fine. Sometimes again the dorsal stripe is the broader of the two, whilst in others the ventral exceeds the dorsal in width. Such considerations render it not unlikely that the species described by Bürger as *E. mediolineata* may be merely a local variety of *E. hemprichi*. The species has a wide range, extending from New Britain in the East Pacific, across the Indian Ocean to the Red Sea.

In a previous paper I mentioned that the excretory system in a specimen of this species (Punnett, 1900, *loc. cit.*) was not provided with ducts. This led me to make sections right through this region in a specimen from the Maldives. The result was a confirmation of the previous statement that the excretory system is here unprovided with ducts opening to the exterior.

3. *Eupolia indica*, n. sp. (Pl. IV. figs. 8, 12, 13, 14.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

A single complete specimen was obtained measuring 22 cm. in length, and with an average breadth of 35 mm. In external appearance much wrinkled and somewhat flattened. There is a well-marked circular head furrow. On the dorsal surface there is a very pale brown stripe about $\frac{1}{4}$ of the body-width. A similar stripe occurs also on the ventral surface.

The skin is fashioned in the style characteristic for the genus. The closely packed layer of cutis glands is about three times the thickness of the epithelium. The connective tissue layer of the cutis is rather thicker than the glandular layer.

The circular muscle layer in the oesophageal region is rather thicker than the inner longitudinal layer. The outer longitudinal layer is stouter than the other two together.

The vascular system in the snout region forms a distinct cephalic loop, though the vessels are very wide and separated only by a thin partition. This loop lies dorsal to the rhynchodaeum, *i.e.* in the same position as the anastomosing lacunae of other species of *Eupolia*. In other respects the vascular system shews no peculiarities marking it off from the usual arrangement such as that found in *E. curta*.

The alimentary canal shews no marked peculiarities.

The proboscis is peculiar in possessing only one layer of muscle fibres, *i.e.* a longitudinal layer. The epithelium is comparatively low.

The excretory system starts about 4 mm. from the tip of the snout. It lies entirely at or below the level of the line joining the nervous side stems. It extends over about 5 mm. It possesses no ducts to the exterior nor any traces of such structures. Fine cords of cells however, which have almost the appearance of delicate ducts compressed to obscure the lumen, pierce the glandular layer of the oesophagus (Pl. IV. fig. 14) and may be traced to the oesophageal epithelium. Such an arrangement recalls the peculiar condition found in *Eupolia melanogramma*[1], though the communications differ probably from this latter species in not being functional.

The brain is much flattened in shape (Pl. IV. fig. 8), its breadth being about three times as great as its depth. The dorsal commissure is thick, straight, and short. The dorsal ganglion lies more lateral than dorsal to the ventral ganglion.

The cerebral organ is not large and is considerably flattened. The ciliated canal passes straight to the inner border of the organ where it dilates into a large spherical vesicle with high epithelium containing a few gland cells (Pl. IV. fig. 12). A small quantity of glandular secretion also occurs within this expansion of the ciliated canal. The dorsal lobe of the dorsal ganglion reaches some way over the cerebral organ. The opening of the cerebral organ is lateral and slightly ventral (Pl. IV. fig. 8). The ciliated canal in this position opens into the circular head furrow, and the circular head furrow in this species is peculiar in being marked by a number of small longitudinal furrows which extend entirely round it (Pl. IV. fig. 8). The epithelium of these small head furrows is characterised by an absence of epithelial glands and by the numerous closely packed oval nuclei (Pl. IV. fig. 13). Along the summits of these small ridges occur small refractive bodies which do not stain. Such head furrows are peculiar to this species of *Eupolia* so far as is known, and recall the small head furrows found in a similar position in the genus *Drepanophorus* ("Kopfgrübchen").

[1] Punnett, *Quart. Journ. Mic. Sc.*, vol. 44, p. 116.

Numerous small eyes occur on the dorsal surface of the snout. They lie for the most part in the cutis, though some are found in the outer longitudinal muscle layer.

The head glands are well developed and are of the typical *Eupolia* type. They reach backwards as far as the level where the excretory tubules start. Anteriorly they open into the well-marked frontal organ.

4. *Eupolia unistriata*, n. sp. (Pl. IV. fig. 4.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

Two specimens were obtained. The larger measures 55 cm. in length, whilst the average breadth is 6 mm., and depth 4 mm. The smaller specimen measures 26 cm. in length and 5 mm. in breadth. In life the worms were white with a black stripe down the back. The width of the stripe is less than 1 mm. In the larger specimen the stripe stops short at the head furrow (Pl. IV. fig. 4), whilst in the smaller one it is continued on to the snout. No markings on the ventral surface.

In external form this species bears a great resemblance to *E. melanogramma* (Punnett, Quart. Journ. Mic. Sc., vol. 44, p. 113). This resemblance is found also in the internal structure. It will be sufficient here to indicate the main points of difference.

The connective tissue layer of the cutis is not so thick as the glandular layer. In *E. melanogramma* these proportions are reversed.

The excretory system possesses numerous openings to the exterior, but it lacks the peculiar ducts opening into the oesophagus which characterise *E. melanogramma.*

The arrangement of the vascular system in the cerebral region is that characteristic of the genus. In *E. melanogramma* the arrangement is slightly different (*loc. cit.* p. 115).

With these exceptions the anatomy of the two species is practically identical. As in *E. melanogramma* there is present also in this species a well-marked sub-anal nervous commissure.

5. *Cerebratulus maldivensis*, n. sp. (Pl. IV. fig. 5, and Pl. V. figs. 3, 6, 9.)

Locality. Miladumadulu atoll, Maldive Is. Dredged in 22 fathoms.

This species is represented by about 30 mm. of fragments. The average breadth is about 1·7 mm. The more posterior portion is much flattened, not measuring more than ·3 mm. in depth. The anterior end is more rounded. The hind end is missing. The proboscis pore is terminal, and the mouth is situated about 2 mm. behind the tip of the snout, which is somewhat pointed. Colour whitish after preservation. No markings present.

The epithelium is thin and contains a few unicellular glands which stain deeply with picric acid. The basement membrane is exceedingly thin (Pl. V. fig. 3). Just below it there is a well-marked layer of circular muscle fibrils and just beneath these again a few longitudinal fibrils which are separated from the outer longitudinal muscle layer by a very thin layer of cutis glands. The whole cutis is but feebly developed.

The outer longitudinal muscle layer in the oesophageal region is about double the thickness of the circular layer. The inner longitudinal layer in this region is of approximately the same thickness as the circular layer. All these three layers are somewhat massive

compared with the size of the worm. Between the dorsal surface of the oesophagus and the proboscis sheath a few longitudinal muscle fibres are present. There is no diagonal muscle layer. A few horizontal muscles occur over the mouth.

The opening of the mouth is situated just before the level where the cerebral organs terminate. The oesophagus is comparatively small and becomes exceedingly constricted posteriorly.

The vascular system shews a well-marked cephalic loop (Pl. V. fig. 9). The buccal commissure is very large. The oesophageal lacunae unite, directly behind the nephridia, to form a single small lateral lacuna on either side, which eventually passes into the lateral vessel. The last named is distinguished from the lacuna by the fact that it has an outer lining of parenchyma cells and gives off small dorsal vascular commissures to the median dorsal vessel at regular intervals. The median dorsal vessel leaves the proboscis sheath just after the termination of the excretory system.

The proboscis is unfortunately lacking. Judging by the small size of the rhynchocoelom it could not have been very large. It was attached very far forwards to the dorsal wall of the sheath just behind the excretory region.

The excretory system is small and confined to the anterior region of the oesophagus. The tubules extend both dorsally and ventrally to the level of the nervous stems. About the centre of the system there is a single excretory duct (Pl. V. fig. 9) on either side which makes an angle of about 45° with the level of the nervous stems.

No gonads are to be distinguished.

The brain is well developed and the dorsal ganglion is double the size of the ventral. Both in the brain and in the nervous side stems the internal fibrous core is more strongly developed than usual. For this reason the nervous side stems are larger and more conspicuous in transverse section than is usually the case, and their large size may possibly be connected with the unusually thick body musculature. A large neurochord cell is present on the ventral and inner surface of each ventral ganglion soon after its separation from the dorsal ganglion. The median dorsal nerve is not well marked. The dorsal brain commissure is short and rather stout. The cerebral organ (Pl. V. fig. 6) is large and ovoid in shape. The glands developed in connection with it are somewhat scanty. It lies at first directly above and then to the inner side of the nervous stem. The head slits reach nearly to the brain. They continue deep a little way after the ciliated canal has been given off.

A frontal organ is present. Eyes are absent. The head glands are very scanty.

6. *Cerebratulus maculatus*, n. sp. (Pl. IV. fig. 1, and Pl. V. figs. 1, 5, 10.)

Locality. Suvadiva atoll, Maldive Is. Dredged from 45 fathoms on mud bottom.

Represented by fragments of a single specimen amounting to 62 mm. Average breadth about 3 mm. Anterior end somewhat rounded, posterior portion much flattened. Hind end lacking. The colour of the preserved specimen is a pale brownish-yellow marked with black spots. These markings are short broken transverse lines in the anterior oesophageal region. A short distance further back they become round, whilst still further back in the posterior oesophageal and intestinal regions they become short longitudinal markings. They are present both on the dorsal and on the ventral surface. (Pl. IV. fig. 1.)

The epithelium is somewhat low, and the nuclei form a well-marked layer at the bases of the cells. In the outer clear portion of the cells are a few unicellular glands, which take a vivid yellow stain with picric acid. A very thin basement membrane separates the epithelium from an exceedingly delicate layer of circular muscle fibrils. Below these again come a few longitudinal muscle fibrils, which are separated from the outer longitudinal muscle layer by a layer of nuclei, apparently representing the cutis glands. The pigment, which gives rise to the black markings of the worm, is situated partly in the cutis (Pl. V. fig. 1) and partly in the nuclear layer of the epithelium. The outer portion of the outer layer of longitudinal muscles is more or less divided into bundles by strands of connective tissue.

Of the muscle layers of the body wall the circular muscle layer is rather thicker than the inner longitudinal but less than half the thickness of the outer longitudinal layer. There are well-marked horizontal fibres over the mouth. The precerebral region is more closely packed with muscle fibres than is usually the case. There is no diagonal muscle layer.

The mouth commences shortly before the level where the cerebral organ terminates. There is no ventral gutter to the intestine.

The vascular system shews a well-marked cephalic head loop. The buccal commissure is well developed. Shortly after the termination of the excretory tubules the oesophageal lacunae are gathered together into a single small lateral lacuna which extends to the intestinal region. Here it acquires a coat of parenchyma cells, and gives off dorsal commissural branches, becoming the lateral blood vessel.

The proboscis is fairly well developed, and shews the three muscle layers characteristic of the Lineid proboscis. Muscle crosses are present.

The excretory system commences soon after the hinder termination of the mouth. There is a median longitudinal tubule running along at the level of the nervous stem. Into it smaller tubules open at intervals, extending a little way above and below the level of the side stems. They are however both small and few in number, the whole excretory system being much attenuated. There is a single duct (Pl. V. fig. 10) on either side about the middle. The lumen of these ducts is also reduced, and it is probable that they were not functional in the living animal.

No gonads are developed.

The brain is not very large. The dorsal ganglia lie directly over the ventral which are closely apposed. Both dorsal and ventral commissures are extremely short. The median dorsal nerve is well marked. Neurochord cells are present in the ventral ganglia though they are not so large as usual. The cerebral organ is fairly well developed though the gland cells in connection with it are somewhat scanty. It lies for the most part dorsal to and just inside the nervous side stems. The head slits reach nearly to the brain and extend backwards to the level where the cerebral organ terminates.

Numerous small eyes are present on the tip of the head just dorsal and ventral to the head slits. Frontal organ and head glands are both absent.

7. *Cerebratulus gardineri*, n. sp. (Pl. IV. figs. 6, 9, and Pl. V. 2, 4, 8.)

Locality. Minikoi, Laccadive Is. From lagoon sand.

Fragments of two specimens preserved, *i.e.* about 73 mm. of one worm and 98 mm. of a somewhat smaller specimen. The latter specimen is almost complete. The breadth is fairly uniform, being about 2·5 mm. in the larger and 2 mm. in the smaller specimen. The intestinal region is somewhat flattened, though not greatly so. The head is sharply pointed, the head slits are long, and the mouth is long and slit-like. Colour when alive white or whitish flesh.

The epithelium is somewhat low and contains a large number of unicellular oral glands. It rests on a thick basement membrane (Pl. V. fig. 2) beneath which is a well-marked layer of circular muscle fibrils. Between this layer and the outer longitudinal muscle layer is the cutis, which contains a few small bundles of longitudinal muscle fibres, traces of cutis glands and a little connective tissue.

The muscles of the body wall are fairly well developed. The outer longitudinal layer is about double the thickness of the circular layer (Pl. IV. fig. 9) in the oesophageal region, and this again is twice as thick as the inner longitudinal layer. The oesophagus is provided with a separate and very delicate coat of longitudinal muscles. There is a strong layer of horizontal muscles over the mouth.

The mouth commences at the level where the cerebral organ terminates, or slightly in front of that level. The intestine possesses a well-marked ventral gutter. The hinder part of the oesophagus is much constricted.

In the vascular system there is present a cephalic loop. Shortly behind the termination of the excretory tubules the oesophageal lacunae are gathered into a single lacuna, which later becomes the lateral blood vessel of the intestinal region as in *C. maldivensis* (p. 107), *C. maculatus* (p. 108). The dorsal blood vessel leaves the proboscis sheath at the level where the oesophageal lacunae are gathered into a single lacuna, *i.e.* rather more than 1 mm. behind the termination of the excretory tubules. The arrangement of the blood lacunae in the cerebral region conforms to the typical Lineid type.

The proboscis is long and fairly stout, being about 1 mm. in diameter. It presents the usual three muscle layers and possesses two muscle crosses.

The excretory tubules first appear in section just before the posterior limit of the mouth. They extend a little way dorsally and ventrally to the level of the nervous stems. In one specimen there was a single duct on either side, making an angle of about 45° (Pl. IV. fig. 9, *exd.*) with the nervous side stems. In the other specimen there was a single duct placed rather in front of the middle of the system on the right side, whilst on the left side there were four ducts, the most anterior of which had almost disappeared.

No gonads were found in either specimen.

The brain is large and the dorsal ganglion is more than double the size of the ventral. The median dorsal nerve is not well marked. Neurochord cells occur on the inner side of each ventral ganglion shortly before its separation from the dorsal ganglion. The median dorsal nerve is not well marked. The cerebral organ is large (Pl. V. fig. 4 *c*), and the gland cells in connection with it are somewhat scanty. The head slits are deep, reaching almost to the brain. At the same time they are exceedingly wide. They continue deep after the ciliated canal has been given off, and terminate at a level slightly behind the posterior end of the cerebral organ.

A frontal organ is present. Numerous small eyes occur, chiefly on the dorsal surface and just beneath the basement membrane. Head glands not well marked.

8. *Cerebratulus ischurus*, n. sp. (Pl. V. fig. 7.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

Fragments of a single specimen amounting to 21 cm. in all. The oesophageal region is rounded in shape, and the breadth here is about 7 mm. The intestinal region is somewhat flattened, and shews a well-marked median ventral longitudinal groove. It measures about 14 mm. in width and about 5 mm. in depth. No record has been preserved of the colour in life. After preservation it is a uniform pale dirty brown.

The epithelium is thin, and contains a few unicellular gland cells. The basement membrane is very thin, and beneath it is a fine layer of circular muscle fibrils and then some longitudinal fibrils separating the last named from the cutis glands. The last are not well developed. The structure of the body wall bears a great resemblance to that of *C. haddoni* (Punnett, Proc. Zool. Soc. 1900, Pl. LV. fig. 8), from which it differs in the somewhat greater development of the cutis glands.

The muscles of the body wall are strongly developed. The outer longitudinal layer is about half as thick again as the circular layer. This in its turn is about double the thickness of the inner longitudinal layer. There is a thick layer of longitudinal muscles between the proboscis sheath and oesophagus. It is continued round the oesophagus as a delicate investment of longitudinal muscle fibrils.

The mouth commences at the hind level of the dorsal ganglion and lies below the cerebral organ.

The vascular system in the snout shews a system of lacunar anastomosing spaces in lieu of a well-marked head loop. The hinder part of the cerebral organ is surrounded by a blood lacuna. The oesophageal lacunae are spacious.

The proboscis is slender. It is two layer as regards musculature, and shews two muscle crosses. The wall of the proboscis sheath is remarkably muscular. Its circular muscle layer is just over half the thickness of the circular muscle layer of the body wall. There is also a delicate outer investment of longitudinal muscle fibrils continuous with the layers separating the proboscis sheath from the oesophagus and circular musculature of the body wall respectively.

The excretory system commences some way behind the mouth. The tubules extend ventral to the nervous side stems and also dorsally to the proboscis sheath. In the anterior fragment cut there was but one excretory duct. Judging from other forms, it is exceedingly probable that had more excretory ducts been present some would have occurred in the comparatively large number of sections through the excretory region. Consequently it is probable that *C. ischurus* is a form with but one pair of excretory ducts.

The brain is small compared with the bulk of the animal. The fibrous core of the dorsal ganglion is about twice the size of that of the ventral ganglion. The dorsal nervous commissure gives off a median dorsal, which for a very short distance behind the brain lies in the outer longitudinal muscle layer, and not between it and the circular layer as is

usually the case, whilst here it gives off a strong proboscis sheath nerve ("untere Rückennerv"). Shortly afterwards it dips down to lie in the normal position between the outer longitudinal and circular muscles. A similar arrangement, though much more marked, occurs in *Oxypolia beaumontiana*[1].

The cerebral organ is small and for the most part much compressed (Pl. V. fig. 7). It possesses a very scanty supply of glands. The head slits are deep, reaching nearly to the brain. They end abruptly where the ciliated canal comes off.

The head glands are fairly well marked. The frontal organ is very small. Eyes absent.

9. *Lineus albovittatus* (STIMPSON, 1857), BÜRGER, 1890.

Locality. Hulule, Male atoll, Maldive Is. From reef.

One specimen measuring 155 mm. in length and 8 mm. in breadth. Its wide distribution has already been noted[2].

10. *Prosadenoporus buergeri*, n. sp.

Locality. Minikoi, Laccadive Is. From beneath a stone in the boulder zone of reef.

A single specimen was obtained. Length after preservation, 70 mm.; breadth, 2·5 mm. The breadth is uniform throughout, and the body is rounded in external appearance. The proboscis was extruded, and measured 35 mm. in length and 1·5 mm. in breadth. Colour in life pink-white.

The epithelium rests on a well-marked basement membrane. The circular muscle layer is considerably thicker than the basement membrane, and is well developed for a metanemertean. The longitudinal muscle layer is several times as thick as the circular layer.

The oesophagus and rhynchodaeum are fused together a little way behind the common opening which is situated nearly terminally on the ventral surface. There is no well-marked ventral blind gut, but where the oesophagus passes into the intestine a single lateral diverticulum is given off from the latter on either side. These two diverticula are spacious and, lying on either side of the oesophagus, extend forwards nearly to the region of the brain. The intestinal diverticula are wide and shallow.

The vascular system presents the usual metanemertean arrangement.

The proboscis sheath extends to the hind end. It possesses an inner layer of longitudinal muscles surrounded by a layer of circular ones. The proboscis is formed on the usual metanemertean plan. It contains 19 nerves.

The excretory system is absent.

The gonads are comparatively undeveloped. They are small sacs containing minute ova. The genus is stated by Bürger to be hermaphrodite, but no traces of testes were to be distinguished in this specimen, though in the other species of the genus this author found ova and spermatozoa both ripe at the same time.

The brain is not large and I have been unable to distinguish neurochord cells. The small cerebral organs lie ventral to and entirely in front of the brain. They open on the ventral surface.

[1] R. C. Punnett, *Quart. Journ. Mic. Sc.* Vol. 44 (in the press).

[2] R. C. Punnett, *Proc. Zool. Soc.* 1900, p. 826.

Two very large eyes are present on either side.

As in the other species of the genus the head glands are exceedingly well developed and reach back a little way past the brain. They open into a deep pit lined by modified ectoderm resembling that figured by Bürger (Naples Monograph, Taf. 18, fig. 12).

The only account of the genus *Prosadenoporus* is that given by Bürger in founding the genus on several species from Amboina (Zeit. f. Wiss. Zool. 1890, p. 30). I have therefore thought it fitting to name this new species in honour of the zoologist to whom our entire previous knowledge of the genus is due. From the account given in this publication it will be seen that the present species differs from the forms there described chiefly in the absence of external markings, the number of proboscis nerves, and in the ventral position of the opening of the canal of the cerebral organ.

11. *Drepanophorus roseus*, n. sp. (Pl. IV. fig. 7.)

Localities. Hulule, Maldive Is. From boulder zone. Naifaro, Fadiffolu atoll, Maldive Is.

Several specimens, most of which were somewhat fragmentary. In three complete specimens the length varied from 50—64 mm. and the breadth from 5—5·5 mm. after preservation. The posterior and middle portions of the body were exceedingly flattened. Colour in life pink to red.

The epithelium is high, and contains numbers of elongated unicellular glands with small granules inside ("Stäbchenzellen"). It is separated from the circular muscle layer by a thick basement membrane. The relative thickness of the three layers, epithelium, basement membrane, and circular muscle layer, is as 4 : 3 : 2. The longitudinal muscular layer is well marked, being of about the same thickness as the preceding three layers together. A thin diagonal layer occurs between the circular and longitudinal.

Mouth and proboscis pore open separately into a common depression on the ventral surface near the anterior extremity. The latter opening is the more anteriorly placed. At first without glands the oesophagus begins to shew large deeply staining unicellular glands in the cerebral region. There is a well-marked ventral blind gut passing forward from the junction of oesophagus and intestine. It does not however reach forwards quite two-thirds of the distance between its point of origin and the brain. The intestine is a small round tube whose area in cross-section is not much more than double that of one of the nervous stems at the same level.

The vascular system conforms to the usual metanemertean arrangement. It contains numbers of large oval corpuscles which render it exceedingly conspicuous in section. The lateral vessels lie just dorsal to the nervous stems, and the commissural vessels which they give off pass directly up between the intestinal diverticula to the median dorsal vessel. Others, however, pass right round the ends of the intestinal diverticula before reaching the median dorsal vessel.

The proboscis sheath presents the usual basket-like arrangement of its muscle fibres which characterises the genus. The diverticula are long and slender, and pass round the intestinal pouches to reach as far as the nervous stem. The proboscis shews the usual

metanemertean structure, and contains twenty-two nerves. The length of the proboscis is about half that of the body.

The excretory tubules are first found in section just after the hinder end of the cerebral organ. When first seen in section the tubules lie laterally and dorsally in the gelatinous connective tissue just beneath the longitudinal muscle layer. As it issues from the nervous ring the lateral blood vessel on either side makes a short bend to the lateral edge of the body before taking up its position just dorsal to the nervous stem. The portion of the vessel forming this bend is somewhat dilated, and the excretory tubules enter into close relation with it. The excretory pore is situated about ·5 mm. behind the termination of the brain on either side. The duct in each case passes round the outer side of the nervous stem and opens on the ventral surface directly beneath it. The excretory tubules extend backwards nearly to the intestinal region, being all the way closely apposed to the lateral blood vessel.

Gonads undeveloped in all the specimens.

The brain is large and round, and the dorsal ganglia have about 4—5 times the area of the ventral in section. The dorsal commissure is very long and slender. The distance between the nervous stems in the intestinal region is about half the width of the body. A small median dorsal nerve occurs between the circular muscles and the basement membrane. Just behind the dorsal commissure a small but well-defined nerve leaves the dorsal ganglion on either side to run along the side of the proboscis sheath just above the diverticula of that structure. It passes into the longitudinal muscles of this region. It is not to be distinguished behind the oesophageal region. Whether this nerve supplies the muscle fibres or whether it passes through the muscles and basement membrane to pass to the skin is doubtful. The fact that it comes off the dorsal ganglion probably indicates a sensory nerve. The nervous stems posteriorly form a well-marked supra-anal commissure. One pair of neurochord cells is present in the brain.

The cerebral organ is large, being in cross section about $\frac{3}{8}$ of the area of the dorsal ganglion at its largest. It lies exactly lateral to the dorsal ganglion and terminates posteriorly at the same level. It possesses a cap of gland cells over its hinder portion, which extends rather further forwards dorsally than ventrally. The opening of the cerebral organ is situated rather in front of the organ and exactly on the lateral edge of the body. There are well-marked little longitudinal head furrows ("Kopfgrübchen") extending some way dorsally and ventrally. The cerebral organ is supplied by one large nerve which comes off the hind end of the dorsal ganglion.

Numerous large eyes are present arranged in four longitudinal rows (cf. Pl. IV. fig. 7.) There are well-marked head glands, but these are short, not extending more than one-third of the distance from the tip of the snout to the brain.

12. *Drepanophorus cerinus.* (BÜRGER. 1890.) (Pl. IV. figs. 10, 11.)

Literature. Bürger, O. Zeit. für Wiss. Zool., 50 Bd. 1890.

Locality. Suvadiva atoll, Maldive Is. From 38 fathoms.

The account given by Bürger is exceedingly short. The small size and the peculiar structure of the cerebral organ, however, render the species fairly easy to identify. I have added below a somewhat fuller account than that given by this author.

Two specimens were obtained measuring about 25 mm. in length and 5 mm. in breadth. The specimens were not quite so flattened dorso-ventrally as most members of this genus, owing to the fact that their bodies were bulged out by ripe gonads. The proboscis is stout and measures about 10 mm. in length. The colour is a very pale pinkish-brown after preservation, and no external markings are distinguishable.

The epithelium is thick and rests upon a very thin basement membrane, which is not nearly so strong as the circular muscle layer just beneath it. The longitudinal muscle layer is strong.

The vascular system presents the usual metanemertean arrangement.

The mouth opens just behind the proboscis pore, but the separation between the two openings is complete. There is not even a depression into which both open as in most species of the genus. In the cerebral region the greater part of the oesophagus (Pl. IV. fig. 10) lies squeezed between the brain lobes. The blind gut extends about half-way from its point of origin towards the brain.

The proboscis sheath shews the usual basket-like arrangement of the muscle fibres. The first few rhynchocoelomic diverticula are exceedingly small, and even in the posterior oesophageal region they reach barely as far as the nervous stems. The proboscis shews the usual structure. It contains but 14 nerves.

The excretory tubules reach forward nearly as far as the opening of the cerebral organ. The excretory pore (which is paired) is about the same distance behind the brain as the front end of the brain is from the tip of the snout. It is ventral in position, and in the specimen cut the duct is much reduced and was probably not functional.

The gonidial sacs of the specimen cut contained large ripe ova. The sacs start in the posterior oesophageal region, and then open just dorsal to the nervous stems on either side. In the intestinal region the openings are ventral near the lateral edge of the body.

The brain is very large, the dorsal ganglion being about 6—7 times the size of the ventral (cf. Pl. IV. fig. 10). The two lobes of the brain are closely apposed, both dorsal and ventral commissures being comparatively short. There is a small median dorsal nerve between the basement membrane and circular muscle layer. The distance between the two lateral stems in the intestinal and in the oesophageal regions is more than half the total breadth of the body of the worm. There is a well-marked supra-anal nerve commissure.

The cerebral organ is very large. It is situated entirely behind the brain. Its opening is rather behind the level where it first appears in section[1]. It is lateral and slightly ventral (cf. Pl. IV. fig. 11). The structure of the organ has already been described by Bürger in the paper referred to above. The essential peculiarity of the organ is the greatly elongated glandular tube which stretches backwards above the nervous stems for a distance which is rather more than double that of the organ itself. The head furrows are well marked and extend round nearly two-thirds of the circumference of the head region.

Large eyes are found, though the number of these is rather smaller than in most species of the genus. About 26 in all are present.

[1] Bürger gives a reconstruction of the organ (*Zeit. für wiss. Zool.* 1890, p. 240) from which it would appear that the organ is not placed entirely behind the brain. This relation may be a local variation and does not appear sufficient to separate the present form as a distinct species.

Synopsis of the genus Drepanophorus.

Since the publication of Bürger's Monograph in 1895 several new species of *Drepanophorus* have been described. With the idea partly of assisting future workers and partly of drawing attention to the gaps in our knowledge I have prepared the small table below by selecting such features as seem likely to prove of use in classification. Since, as can be seen from this table, the gaps in our knowledge are considerable, it is not yet possible to arrange the existing species in any order expressing their relationships. Roughly it may be said that the majority of the genus conform to a certain type of which *D. crassus* may be taken as the example. More or less closely resembling this species are the European *D. igneus* and *D. albolineatus*, together with the exotic forms *D. latus*, *D. lifuensis*, and *D. roseus*. The remaining species are, so far as can be seen, more widely separated from one another. The enormous development of the glandular portion of the cerebral organ characterises *D. cerinus* and, to a lesser degree, *D. willeyanus*. *D. lankesteri* is conspicuous by the ventral position of the gonidial pores, the fusion of the anterior rhynchocoelomic pockets, and the regularity of its ventral nerve commissures. Perhaps the form, which differs most from the rest, is *D. borealis*, the only Arctic species known. In its broad, stumpy body, the ventral openings of the cerebral organ, the dorsal position of the gonidial pores, the small number of eyes, and the peculiar expansions of the rhynchocoelom over the brain it stands apart from the remaining species.

In order to include the more recent species the diagnosis of the genus below shews a few points of difference from that given by Bürger, though these are by no means numerous or very important.

Genus *Drepanophorus*.

Flattened forms exhibiting a relatively great breadth in comparison to their length.

The mouth and rhynchodaeum open separately. The proboscis is large and contains 14—32 nerves. Its armature is characteristic for the genus.

The proboscis sheath gives off lateral diverticula alternating regularly with the gut pockets.

The nervous stems are ventral in position and the distance between them is seldom more than half the diameter of the body laterally. They unite posteriorly above the anus.

The cerebral organ is large and never lies in front of the brand.

Small longitudinal head furrows ("Kopfgrübchen") are developed in connection with the circular head furrow.

Neurochord cells occur in the ventral ganglia.

The eyes may be few or numerous but are always of large size.

Head glands but slightly developed.

The sexes are separate. The gonads exhibit great divergence in the number and position of their ducts.

	*Literature (see below)	Position of opening of cerebral organ	Position of cerebral organ	Eyes	Proboscis nerves	Gonidial pores	Peculiar features
D. crassus (=serraticollis)	(1), (2), (3), (4), (5), (6)	Lateral		>30	19—20	1 lateral to each intestinal diverticulum	
D. spectabilis (=rubrostriatus)	(1), (2), (3), (4), (5), (6)	Lateral	Beside and rather beyond brain	>30	24		
D. lankesteri	(2)		Behind brain			2 ventral to each intestinal diverticulum	Anterior rhynchocoelomic diverticula fuse. Nephridial pore at post. end of nephridium
D. latus	(4), (6), (7)	Lateral, rather dorsal		>30	>30		
D. cerinus	(4), (6), and this paper	Lateral and rather ventral	Behind brain	<30	14	1 ventro-lateral to each intestinal diverticulum	Very long posterior glandular process to cerebral organ
D. massiliensis	(5)						
D. igneus	(6)				14		
D. albolineatus	(6)	Lateral and slightly ventral		>30			
D. lifuensis	(8)	Lateral	Beside and not behind brain	>30	>30		
D. willeyanus	(8)	Lateral	Chiefly behind brain	<20	16	1 lateral to each intestinal diverticulum	Long posterior glandular process to cerebral organ
D. borealis	(9)	Ventral	Beside and not behind brain	<20	14	3 dorsal to each intestinal diverticulum	Anterior rhynchocoelomic diverticula fuse and form expansions over brain
D. roseus	This paper	Lateral	Beside and not behind brain	>30	22		

* List of more important or more recent papers referring to the genus :—

(1) Hubrecht, A. A. W. The genera of European Nemerteans critically revised. Notes. *Leyden Mus.* 1879.
(2) Hubrecht, A. A. W. The Nemerteans, *Challenger Reports*, Vol. 19. 1887.
(3) Joubin, L. *Archiv de Zool. Exp. et Gen.* 1890.
(4) Bürger, O. *Zeit. für wiss. Zool.* 1890.
(5) Joubin, L. *Faune française.* 1894.
(6) Bürger, O. Die Nemertinen. *Fauna und Flora des Golfes von Neapel.* 1895.
(7) Staub, J. Semon's *Zoologische Forschungsreisen.* 1900.
(8) Punnett, R. C. Willey's *Zoological Results*, Pt. V. 1900.
(9) Punnett, R. C. *Proc. Zool. Soc.* 1901.

EXPLANATION OF PLATES.

bm = basement membrane.
c = cutis.
cc = ciliated canal.
ccep = expanded end of ciliated canal.
corg = cerebral organ.
dbv = dorsal blood vessel.
ddg = dorsal lobe of dorsal ganglion.
dg = dorsal ganglion.
ep = epithelium.
exd = excretory duct.
ext = excretory tubule.
fr = frontal organ.
glcorg = glands of cerebral organ.
hf = head furrow.
*hs** = head slit.
lvl = lateral vascular lacuna.
m = mouth.
mc = circular muscle layer.
mcc = circular muscle layer of cutis.
mci = internal circular muscle layer.
ml = longitudinal muscle layer.
mlc = longitudinal muscle layer of cutis.
mli = internal longitudinal muscle layer.
mlo = outer longitudinal muscle layer.
nd = median dorsal nerve.
ns = lateral nervous stem.
oc = eyes.
oep = oesophageal epithelium.
oes = oesophagus.
ogl = oesophageal glandular layer.
ol = oesophageal vascular lacunae.
p = proboscis.
pg = pigment.
ps = proboscis sheath.
rhc = rhynchocoelom.
vcl = vascular cephalic lacuna.
vg = ventral ganglion.

PLATE IV.

FIG. 1. *Cerebratulus maculatus.* Dorsal and ventral view of anterior end. × 2.

FIG. 2. *Eupolia hemprichi.* Dorsal and ventral view of anterior end. × 1.

FIG. 3. *E. hemprichi.* Anterior end of another specimen from dorsal surface. × 2.

FIG. 4. *E. unistriata.* Anterior end from dorsal surface. × 1.

FIG. 5. *Cerebratulus maldivensis.* Ventral view of anterior end. × 4.

FIG. 6. *C. gardineri.* Ventral view of anterior end. × 2.

FIG. 7. *Drepanophorus roseus.* Ventral view of anterior extremity. From specimen cleared in cedar oil. × 5.

FIG. 8. *Eupolia indica.* Section through region of head furrow, shewing outline of brain. × 22.

FIG. 9. *Cerebratulus gardineri.* Section through oesophageal region, shewing relative thickness of muscle layers and position of excretory duct. × 15.

FIG. 10. *Drepanophorus cerinus.* Section through brain region immediately after the separation of the dorsal and ventral ganglia. × 45.

FIG. 11. *D. cerinus.* Section just anterior to the opening of the cerebral organ. × 45.

FIG. 12. *Eupolia indica.* Section through cerebral organ and hinder part of dorsal ganglion. × 45.

FIG. 13. *E. indica.* Grooved epithelium of circular head furrow as seen when more highly magnified than in Fig. 8.

FIG. 14. *E. indica.* Section through portion of oesophagus in excretory region, shewing a cord of cells from an excretory tubule* piercing the oesophageal glandular layer and reaching to the inner surface of the alimentary canal. × 80.

* The asterisk marks the level where the dorsal vessel emerges from the proboscis sheath.

FIG. 15. *Cephalothrix aliena.* Section through body wall in hinder part of oesophageal region. The greater portion of the section is somewhat dorsal to the level of the nervous stem. × 80.

FIG. 16. *Cephalothrix aliena.* Section through anterior part of oesophageal region. × 45.

PLATE V.

FIG. 1. *Cerebratulus maculatus.* Section through skin of oesophageal region. × 160.

FIG. 2. *Cerebratulus gardineri.* Section through skin in oesophageal region. × 110.

FIG. 3. *Cerebratulus maldivensis.* Section through skin of oesophageal region. × 110.

FIGS. 4—7. Sections taken at intervals through the hind brain and cerebral organ of the following species:

FIG. 4 (*a*—*c*). *C. gardineri.* At intervals of 80 μ.

FIG. 5 (*a*—*c*). *C. maculatus.* At intervals of 100 μ.

FIG. 6 (*a*—*c*). *C. maldivensis.* At intervals of 80 μ.

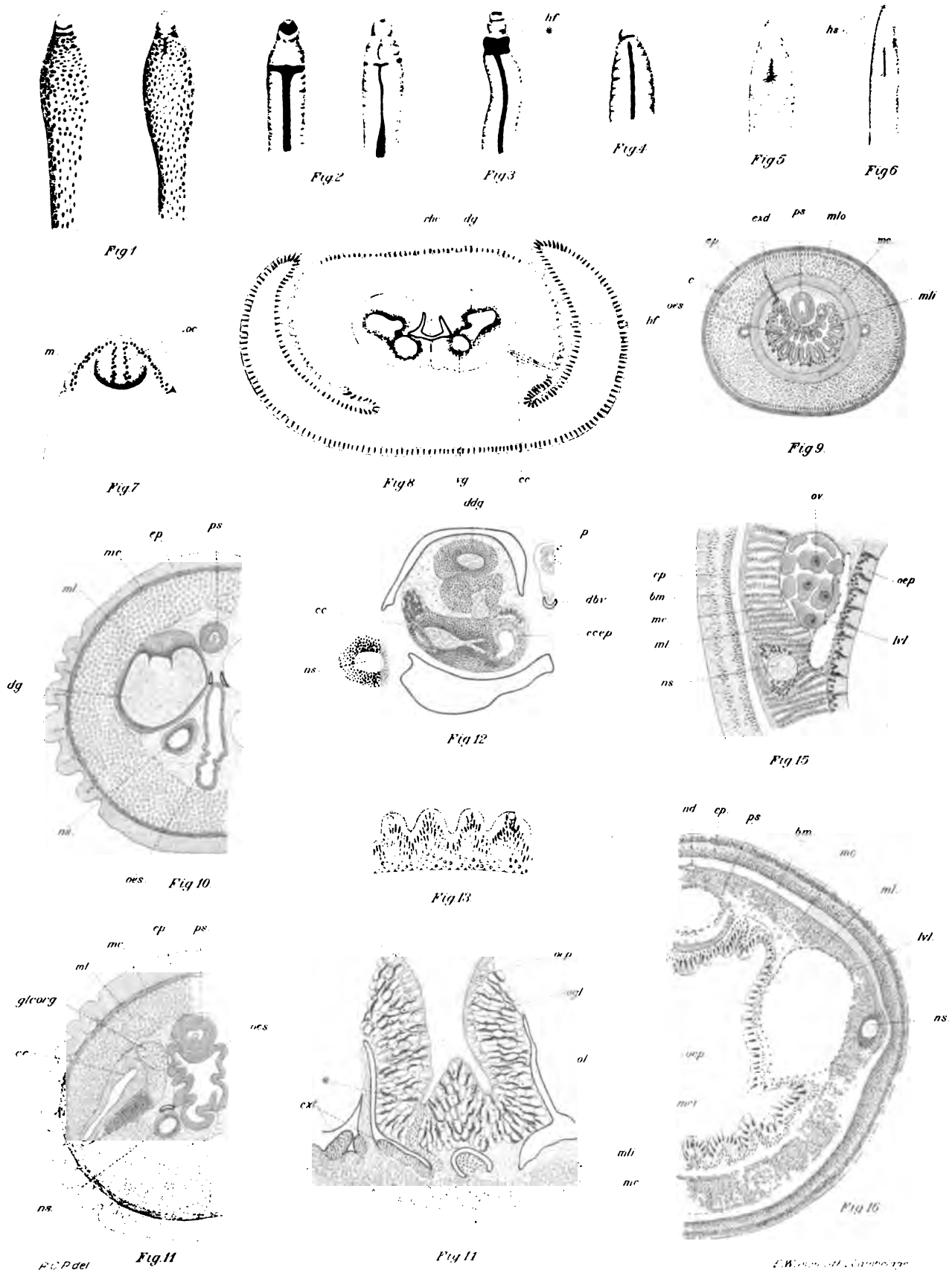
FIG. 7 (*a*—*c*). *C. ischurus.* 50 μ between *a* and *b*; 150 μ between *b* and *c*.

FIGS. 8—10. Schematic reconstructions through the anterior end of several Lineidae. The buccal vascular vessels, the oesophageal nerves, the proboscis and its sheath, have, for the sake of simplicity, been omitted. The oesophageal vascular lacunae have also been represented as simple vessels.

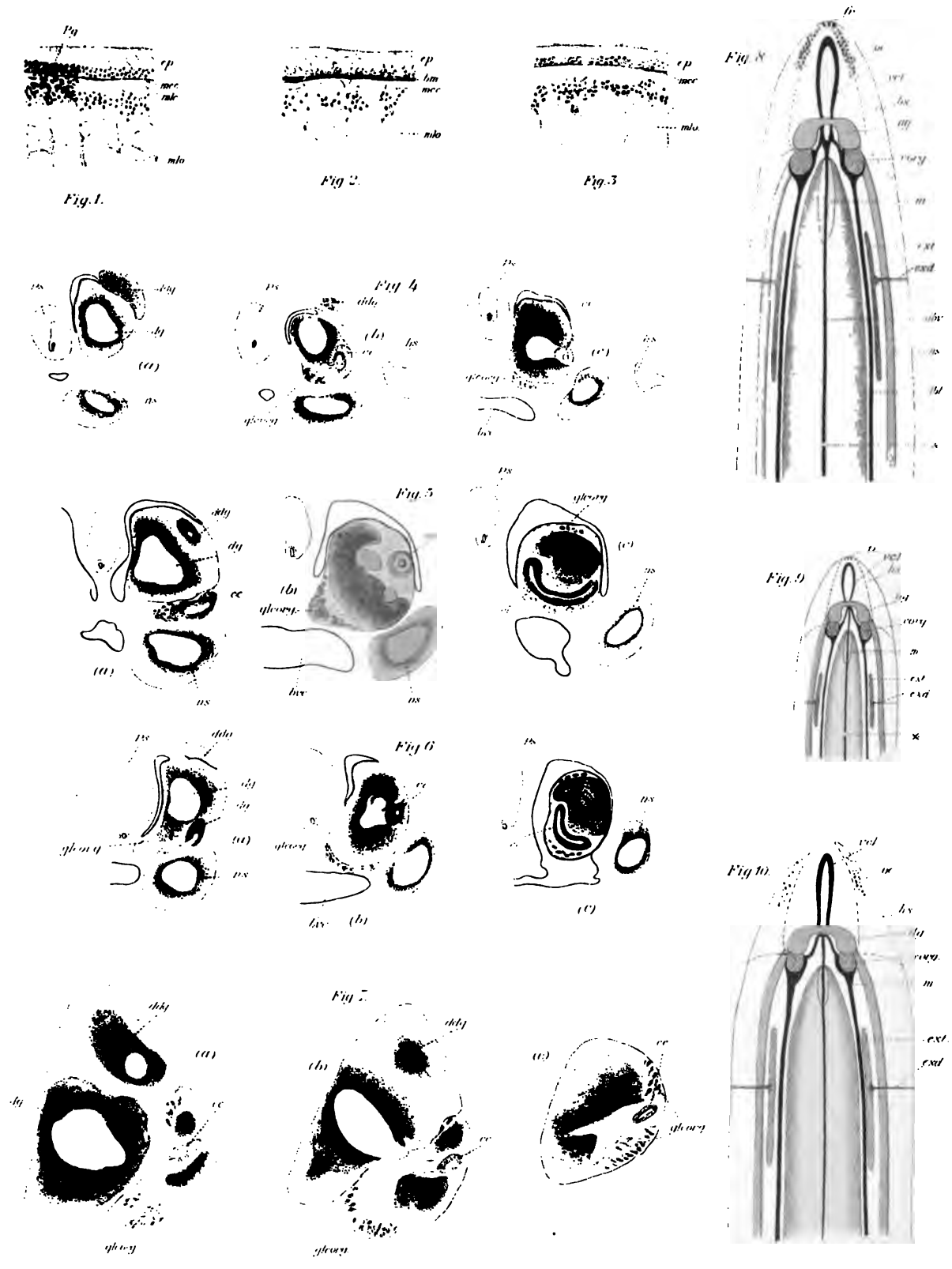
FIG. 8. *C. gardineri.* × 10.

FIG. 9. *C. maldivensis.* × 10.

FIG. 10. *C. maculatus.* × 10.



Punnett - Nemertea



R.C.P. del.

A. Wilson, Cambridge

Punnett – Nemertea

AMPHIBIA AND REPTILIA.

By F. F. Laidlaw, B.A. (Cantab.), *Demonstrator in Zoology at the Owens College, Manchester.*

With the single exception of *Lygosoma albopunctatum* every specimen contained in the collection belongs to a species which is abundant in Ceylon and in many cases through the Oriental region (e.g. *Hemidactylus frenatus, Typhlops braminus* and *Rana tigrina*). *Lygosoma albopunctatum* has not so far as I am aware been recorded from Ceylon. One or two species are characteristic Singhalese forms, viz. *Aspidura trachyprocta* and *Nicoria trijuga*. It is evident then that the reptilian fauna of these islands shows the closest connection with the fauna of Ceylon, and this is what one would expect, when the political and commercial dependence of these islands upon Ceylon is taken into consideration[1].

I have not been able to compare the specimens of *Bufo melanostictus* with a series from elsewhere. The differences between the two varieties, spoken of below (p. 120), though slight are yet sufficiently well-marked to attract attention.

So far as I can discover no account has hitherto been given of the herpetological fauna of the two archipelagoes. In the following list I have referred only to Boulenger's British Museum Catalogues, but another account of all the species may be found in the same author's volume on the Amphibia and Reptilia in the "Fauna of British India."

I take this opportunity of thanking Mr Boulenger for his assistance in naming some specimens, and I am much indebted to Mr Stanley Gardiner for asking me to describe his collection.

AMPHIBIA.

Fam. **Ranidae.**

1. *Rana tigrina* Dana.

Rana tigrina, Boulenger, *Cat. Batr. Sal.* p. 26 (1882).

A single female, a perfectly typical example of the species, from Minikoi, Laccadives. Range from the Philippine Islands and China to Ceylon.

[1] [The close connection with Ceylon is probably a growth of quite recent date. The principal trade relations of the 16th, 17th and 18th centuries were with the south-west coast of India. There has always been until recent years constant intercourse both with Arabia and Malaysia as well. Ed.]

Fam. **Bufonidae.**

2. *Bufo melanostictus* Schneid.

Bufo melanostictus, Boulenger, *Cat. Batr. Sal.* p. 306 (1882).

Several specimens of this toad were obtained by Mr Stanley Gardiner, two at Hulule, Male Atoll, the rest at Maradu in the Addu Atoll. The two former differ from the rest of the specimens in having the skin of the back distinctly less warty and the interorbital space perfectly smooth. The measurements of the largest individual (from Hulule) are as follows:—

Snout to vent	48 mm.
Thigh to knee	10 mm.
Knee to ankle	18 mm.
Ankle to end of 4th toe	28 mm.

The species is widely distributed in the Oriental region, ranging from China and the Philippine Islands westwards to Ceylon and India. It has also been introduced into Mauritius.

REPTILIA.

Order LACERTILIA.

Fam. **Geckonidae.**

1. *Hemidactylus frenatus* (Schleg.).

Hemidactylus frenatus, Boulenger, *Cat. Liz.* I. p. 120 (1885).

This widely distributed animal is evidently abundant throughout the Maldives and in Minikoi. Thirty-four specimens were obtained from 14 different localities extending from Minikoi to Addu Atoll. The species ranges from Ceylon and the islands of the Indian Ocean to China, the islands of the Western Pacific, and to St Helena.

2. *Hemidactylus gleadovii* Murray.

Hemidactylus gleadovii, Boulenger, *Cat. Liz.* I. p. 129 (1885).

Four geckoes from Hulule, Male Atoll, are to be referred to this species. The largest specimen, a female, has the following measurements:

Length of head	13·5 mm.
„ „ body	28·5 mm.
„ „ tail (regenerated)	29 mm.

Of the two males one has a series of 12 preanal pores, while the other has no fewer than 30, but in other respects does not differ from the first.

The species is found in India, Ceylon, S. China and Burmah.

Fam. **Agamidae.**

3. *Calotes versicolor* (Daud).

Calotes versicolor, Boulenger, *Cat. Liz.* I. p. 321 (1885).

This lizard appears to be very abundant in the Maldive Islands. Twenty-seven specimens, mostly quite young (measuring from 20 mm. to 25 mm. from the tip of the snout to the root of the tail), were obtained at the following localities: Goidu, Goifurfehendu Atoll, Hulule, Male Atoll, Fainu, N. Mahlos Atoll, Maduwari, S. Mahlos Atoll, and Maradu, Addu Atoll.

The largest individual, a male from Goidu, measured 65 mm. from the tip of the snout to the vent. The lateral scales in the small specimens are much more strongly keeled than in the more mature individuals. In fact the larger a specimen the smoother its lateral scales.

The species ranges from India and Ceylon to China and Siam.

Fam. **Scincidae.**

4. *Lygosoma albopunctatum* (Gray).

Lygosoma (*Riopa*) *albopunctatum*, Boulenger, *Cat. Liz.* III. p. 309 (1887).

This small skink is plentiful in the islands and 14 specimens were obtained in Minikoi, Laccadives, at Mahdu, S. Mahlos Atoll, Limbo-Kandu and Inguradu, N. Mahlos Atoll, Manadu, Miladumadulu Atoll, and Hulule, Male Atoll. The specimens are considerably smaller than the type, an average specimen measuring as follows:

Length of	head	6 mm.
„ „	body	24 mm.
„ „	tail	40 mm.
„ „	fore-limb	5 mm.
„ „	hind-limb	8 mm.

The species inhabits India, Burmah and the Malay Peninsula.

Order OPHIDIA.

Fam. **Typhlopidae.**

5. *Typhlops braminus* (Daud).

Typhlops braminus, Boulenger, *Cat. Snakes*, I. p. 16 (1893).

This species occurs all over the Oriental region and in S. Africa. The collection contains two specimens from Minikoi, Laccadives, and a third from Manadu in Miladumadulu Atoll. The Minikoi specimens measure 128 mm. total length by 2·75 mm. diameter of body (colour black-brown) and 132 mm. by 2 mm. (colour light brown), while the Manadu specimen measures 172 mm. by 4 mm. (colour grey-black).

Fam. **Colubridae.**

6. *Aspidura trachyprocta* Cope.

Aspidura trachyprocta, Boulenger, *Cat. Snakes*, I. p. 313 (1893).

A single specimen from Male, Male Atoll. The species is otherwise peculiar to Ceylon.

7. *Lycodon aulicus* (Linnè).

Lycodon aulicus, Boulenger, *Cat. Snakes*, I. p. 352 (1893).

The two specimens, which are from Hulule, Male Atoll, both belong to var. *A*, which is peculiar to Ceylon and S. India. The species ranges as far as Timor and Celebes.

8. *Hydrus platurus* (Linnè).

Hydrus platurus, Boulenger, *Cat. Snakes*, III. p. 267 (1896).

A single specimen belonging to var. *E*. The species inhabits the tropical waters of the Indian and Pacific Oceans.

Order CHELONIA.

Fam. **Testudinidae.**

9. *Nicoria trijuga*, var. *thermalis* (Lesson).

Nicoria trijuga, var. *thermalis*, Boulenger, *Cat. Chel.* p. 122 (1889).

Seven specimens from Hulule, Male Atoll. The largest measured 118 mm. and the smallest 68 mm. along the carapace. This variety of the species has been introduced into Diego Garcia, Chagos Archipelago, but is otherwise peculiar to Ceylon.

Fam. **Chelonidae.**

10. *Chelone mydas* (Linnè).

Chelone mydas, Boulenger, *Cat. Chel.* p. 180 (1889).

11. *Chelone imbricata* (Linnè).

Chelone imbricata, Boulenger, *Cat. Chel.* p. 183 (1889).

Both this and the last species are of universal distribution in tropical and sub-tropical seas, and are exceedingly numerous in the Maldives and Laccadives.

LEPIDOPTERA.

By Ed. Meyrick, B.A. (Cantab.), F.Z.S.

The collection includes 67 species, of which one cannot safely be identified. Almost all the others—probably all but one—occur also in India or Ceylon. The solitary exception is *Notarcha penthodes*, a representative form which in Minikoi replaces the common and widely distributed *N. multilinealis*. The only other species not actually known to me as occurring in India or Ceylon is *Eucosma leucaspis*, but the Indian *Tortricina* are little studied, and it will probably be found to occur there.

Fam. **Arctiadae.**

1. *Celama squalida* Stgr. Minikoi, 1.
2. *Utetheisa antennata* Swinh. Hulule, 11.

Fam. **Caradrinidae.**

3. *Polytela gloriosae* F. Minikoi, 1.
4. *Melanchra consanguis* Gn. Minikoi, 1.
5. *Caradrina obtusa* Hamps. Minikoi, 1; Hulule, 1.

Fam. **Plusiadae.**

6. *Hydrillodes lentalis* Gn. Minikoi, 13.
7. *Simplicia robustalis* Gn. Minikoi, 2; Hulule, 1.
8. *Hypena indicatalis* Walk. Minikoi, 4.
9. „ *jussalis* Walk. Hulule, 2.
10. *Grammodes mygdon* Cr. Minikoi, 12; Hulule, 1.
11. *Ophiusa coronata* F. Minikoi, 1.
12. „ *metaspila* Walk. Minikoi, 5.
13. *Plusia permissa* Walk. Minikoi, 1; Hulule, 4.
14. *Leocyma sericea* Hamps. Minikoi, 8; Hulule, 6.
15. „ *cygnus* Walk. (?) Minikoi, 1, but in too poor condition to identify certainly.
16. *Hyelopsis signifera* Walk. Minikoi, 1; Hulule, 2.

Fam. **Hyblaeidae.**

17. *Hyblaea puera* Cr. Hulule, 8.

Fam. **Ocneriadae.**

18. *Euproctis varians* Walk. Minikoi, 12.

Fam. **Sterrhidae.**

19. *Leptomeris aspilataria* Walk. Minikoi, 6.
20. „ *actuaria* Walk. Hulule, 1.
21. „ *caesaria* Walk. Hulule, 1.
22. „ *addictaria* Walk. Minikoi, 1.
23. *Anisodes annulifera* Hamps. Hulule, 1.

Fam. **Geometridae.**

24. *Eucrostis rectifasciata* Hamps. Hulule, 1.

Fam. **Selidosemidae.**

25. *Ascotis boarmiaria* Walk. Minikoi, 11.
26. *Hyperythra lutea* Cr. Hulule, 1.

Fam. **Sphingidae.**

27. *Cephonodes hylas* L. Minikoi, 1.
28. *Macroglossa sitiene* Walk. Minikoi, 6.
29. „ *gyrans* Walk. Hulule, 4.
30. *Deilephila theylia* L. Minikoi, 8; Hulule, 6.

Fam. **Nymphalidae.**

31. *Anosia plexippus* L. Hulule, 1.
32. *Vanessa montana* Feld. Hulule, 1.
33. „ *cardui* L. Hulule, 1.

Fam. **Satyridae.**

34. *Mycalesis mandata* Moore. Hulule, 7.
35. „ *polydecta* Cr. Minikoi, 9; Hulule, 1.

Fam. **Lycaenidae.**

36. *Spalcis epius* Westw. Minikoi, 12.
37. *Zizera gaika* Trim. Minikoi, 2; Hulule, 7.
38. *Catochrysops osiris* Hopff. Hulule, 7.

Fam. **Papilionidae.**

39. *Papilio hector* L. Hulule, 3.

Fam. **Hesperiadae.**

40. *Baoris colaca* Moore. Minikoi, 39; Hulule, 7.

Fam. **Phycitidae.**

41. *Canthelea lateritialis* Walk. Minikoi, 1.
42. *Melathrix praetextella* Christ. Hulule, 2.

Fam. **Pyraustidae.**

43. *Schoenobius immeritalis* Walk. Hulule, 1.
44. *Nymphula depunctella* Gn. Hulule, 1.
45. *Leucinodes orbonalis* Gn. Minikoi, 1.
46. *Pleonectusa admixtalis* Walk. Minikoi, 11; Hulule, 16.
47. *Epichronistis acrospila* Meyr. Minikoi, 13; Hulule, 12.
48. *Molybdantha tricoloralis* Z. Minikoi, 5; Hulule, 3.
49. *Hydriris ornatalis* Dup. Minikoi, 3.

50. *Ischnurges gratiosalis* Walk. Minikoi, 24, a local form having the yellow ground of forewings less obscured with rosy suffusion than usual; Hulule, 4, normal.

51. *Phakellura indica* Saund. Hulule, 1.

52. *Margaronia suralis* Ld. Minikoi, 13, a local form having the discal black dots always obsolete on upper surface; Hulule, 12, normal.

53. *Margaronia bivitralis* Gn. Hulule, 1.

54. *Omiodes niphealis* Walk. Minikoi, 59; Hulule, 7.

55. „ *diemenalis* Gn. Hulule, 8.

56. *Hymenia recurvalis* F. Minikoi, 1; Hulule, 1.

57. *Conogethes suralis* Walk. Minikoi, 2.

58. *Notarcha penthodes* n. sp.

Differs from *N. multilinealis* Gn. only in having on both wings a sharply defined dark fuscous terminal fascia from apex to tornus, cut by pale streaks on veins.

Minikoi, 5 specimens; this is clearly a representative form of *N. multilinealis*, and I can detect no difference whatever except in the character given; yet since this character is conspicuous and apparently constant, and I have never met with it elsewhere, I think the facts are best exhibited by giving the form specific rank; no doubt it is a case where opinions may vary.

59. *Notarcha multilinealis* Gn. Hulule, 18, normal.

Fam. **Pyralididae.**

60. *Endotricha mesenterialis* Walk. Minikoi, 1; Hulule, 2.

Fam. **Thyrididae.**

61. *Striglina scitaria* Walk. Minikoi, 16; Hulule, 3.

Fam. **Pterophoridae.**

62. *Sphenarches caffer* Z. Hulule, 1.

Fam. **Heterogeneidae.**

63. *Natada sericea* Hamps. Hulule, 9.

Fam. **Epiblemidae.**

64. *Eucosma leucaspis* n. sp.

♂ 14—15 mm. Head, thorax, and abdomen dark fuscous, abdomen sometimes yellowish towards base beneath. Forewings moderate, elongate, posteriorly dilated, costa gently arched, apex obtuse, termen bowed, vertical; grey, slightly purple-tinged, strigulated with dark fuscous; upper half of central fascia blackish, moderately broad, oblique, followed by a triangular white costal patch extending to beyond $\frac{3}{4}$ of costa, tinged posteriorly towards costa with rosy-ochreous, its discal angle truncate and indented by a short blackish strigula; costal edge from central fascia to apex blackish, with pairs of white strigulae; beyond this patch a blackish blotch, semicircular above, not reaching costa, suffused beneath; ocellus including three longitudinal blackish marks, its posterior edge indicated by grey-whitish suffusion. Hindwings dark fuscous.

Minikoi, 3 specimens.

Fam. **Tortricidae.**

65. *Adoxophyes euryomis* n. sp.

♂ 17 mm., ♀ 19—20 mm. Head and thorax ochreous, palpi rather long. Abdomen pale ochreous, in ♂ with very long anal and genital tufts. Forewings moderate, oblong, costa strongly arched towards base, then straight, apex obtuse, termen slightly sinuate-bowed, vertical, costal fold of ♂ very broad, reaching from base to middle of costa; light yellow-ochreous, more or less tinged or sprinkled irregularly with reddish-brown; markings reddish-fuscous, edged with pale strigae; edge of basal patch indicated by an irregular streak from $\frac{1}{4}$ of costa to $\frac{2}{5}$ of dorsum, angulated below middle; central fascia from before middle of costa to before tornus, narrow, rather irregular, abruptly quadrangularly dilated posteriorly below middle; a curved irregular streak from before $\frac{3}{4}$ of costa to near termen above tornus, confluent beneath with a slender subterminal streak rising from a small spot on costa before apex. Hindwings rather light ochreous-fuscous, costa broadly ochreous-whitish.

Minikoi, 16 specimens; Hulule, 7. Occurs also in India.

Fam. **Plutellidae.**

66. *Simaethis submarginalis* Walk. Hulule, 4.

ECHIUROIDEA.

By A. E. Shipley, M.A., *Fellow and Tutor of Christ's College, Cambridge, and University Lecturer in the Advanced Morphology of the Invertebrata.*

(With Plate VI.)

The collection of Echiuroids from Minikoi and the Maldive Islands contained few species and few specimens. Obviously they are shy animals and easily elude the search of the collector. Six species in all were found represented by some seventeen specimens. At Minikoi but two specimens of *Thalassema diaphanes*, one very small, and one specimen of *Thal. moebii* were taken. The Maldive Island specimens were, with the exception of the *Bonellia*, all taken at Hulule on the Male Atoll; they include examples of *Bonellia viridis*, *Thal. diaphanes*, *Thal. erythrogrammon*, *Thal. moebii*, *Thal. semoni* and *Thal. vegrande*. It is noticeable that all the species belong to the two genera of Echiuroids which are frequenters of the warm and temperate seas. The plate which accompanies this paper contains four coloured sketches, drawn by Mr C. Forster Cooper, accurately representing the hues of the living animals.

I have not thought it worth while to take up space by repeating the lists of literature given in my paper "On a Collection of Echiuroids from the Loyalty Islands, New Britain and China Straits, with an attempt to revise the Group and to determine its Geographical Distribution," published in Willey's *Zoological Results*, but under each species I have given a reference to the page of that article, upon which the literature will be found.

I. Genus BONELLIA Rolando.

1. *Bonellia viridis* Rolando.

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 341.

A single medium-sized specimen of a blackish green colour, very dark.

Locality. Maduwari, S. Mahlos Atoll, Maldive Islands; found in the lagoon reef but never seen elsewhere in the Group. It is a widely distributed species, occurring in the Mediterranean and Adriatic and off Norway. Dr Willey collected it at the Loyalty Islands and saw specimens of it in the D'Entrecasteaux Group. It also occurs off the Australian and British New Guinea coasts.

II. Genus THALASSEMA (Gaertner) Lamarck.

2. *Thalassema diaphanes* Sluiter. (Plate VI, fig. 2.)

Shipley. Willey's *Zoological Results*, Part III. 1899, pp. 336 and 346.

A single specimen, 2·5 cm. long, from Hulule. Greatest breadth 8 mm. The animal was curved and the skin of the outer curvature was remarkably thin. The contents of the alimentary canal was in very obvious pellets, as is usually the case in this species. Another bottle containing three specimens from the same locality was labelled "in *Halimeda* masses." Two specimens, one very small, were taken at Minikoi. The smaller was taken "from lagoon sand between the roots of a branching *Porites*," the larger from "sand under stones of reef-flat"; when living this specimen had a proboscis, which when expanded reached a length of 2·7 cm. and its body was nearly as long.

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands. This species has previously been described from the Bay of Batavia and from off Pigeons' Island, New Britain.

As this is the first mention of Hulule I insert here a note drawn up on the spot by Mr Stanley Gardiner on the Echiuroids of that locality:—

"*Thalassema* alone occurs. There seem to be three species, which live in and under the stones of the boulder zone, east and west. A fourth small species—perhaps different—light green colour, rather transparent (*Thalassema diaphanes* A. E. S.)—is found in *Halimeda* masses, but otherwise we have not found any except in the above positions. They are far more numerous to the east. The two specimens of the large species (*Thalassema erythrogrammon* A. E. S.) were obtained under a large stone on sand, close to inside of boulder zone to east. They live quite well for 20 to 30 hours in water in a covered basin, and kill best for museum purposes by very slowly adding dilute Chromic Acid. Alcohol sooner or later causes collapse, however slowly the anaesthesia is performed."

3. *Thalassema erythrogrammon* Max Müller. (Plate VI, fig. 1.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 347.

A single, very large specimen whose dimensions, judging from a life-size sketch made by Mr C. Forster Cooper of the living animal, were:—length of body 39 cm., length of proboscis 11 cm., greatest width of body 4 cm. The posterior end of the body, which is very rugged and pitted, extended some 4 cm. from the extreme end. The specimen preserved in spirit which reached my hands had contracted to about one quarter of the above length. The proboscis, which was extremely contracted and had broken off the body, was but 3 cm. long, and was all bunched up like an acorn in outline.

The colour of the animal differs but little from what has hitherto been described. The ventral surface of the proboscis was yellow with a thin violet stripe as is usual. The fourteen longitudinal muscles were of a purplish red hue with greenish interspaces, and the posterior pitted portion was violet. The animal as Mr Cooper described it "pulsated horribly," and as the contractions passed along the body the areas, which coincided with the point of intersection of the longitudinal and transverse muscles, swelled up into prominent, light-pinkish knobs.

The alimentary canal was full of pieces of coral rock, some of considerable dimensions. Mr J. Stanley Gardiner has been good enough to examine a small specimen of the contents of the intestine and has kindly furnished me with the following list of its varied components:—

"One piece of *Madrepora*, end of a branch, corallum not at all worn down, 13 mm. long by 6·5 mm. in diameter, spines etc. still perfect and cells full of animal tissues: five pieces of *Pocillipora*, the largest 14 × 10 mm.: fragments of *Distichopora*: Lamellibranch and Gastropod shells, two of the latter perfect, apparently having recently contained the living animals: leaves of *Halimeda* and similar Algae in great numbers: Millepore and *Polytrema* fragments: *Calcarina* and other Foraminifera: one Polyzoon fragment: a little bunch of Hydroid remains. The rest of the sample was sand composed mainly of fragments of any of the above.

"The contents appear to indicate that the animal may browse directly on sedentary animals and plants besides taking in sand quite, as it were, passively."

A second specimen from the same locality was too macerated for accurate measurements but it was certainly not smaller than the above.

Locality. Hulule, Male Atoll, Maldive Islands. This is not far from the centre of the known area of distribution of the species, which extends from New Guinea to the Red Sea and as far south as the Isle of Bourbon.

4. *Thalassema moebii* Greef. (Plate VI, figs. 3, 3 *a*, 3 *b*.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 350.

One specimen, 6 cm. long, 1 cm. in diameter. In the living specimen the proboscis was almost as long as the body, but it contracted to one-fifth the body length in dying. The three nephridia were crowded with eggs. Mr Cooper's sketch faithfully reproduces the greyish-yellow passing into violet colour of the animal with its violet stripes running spirally round the body. Another bottle contained six specimens, taken at the same place as the above. This contains a label recording that the specimens were found under stones. A second specimen, from Minikoi, was found "in sand under a loose stone of the boulder zone."

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands, also recorded from Mauritius, Upolu and Amboyna.

5. *Thalassema semoni* Fischer. (Plate VI, fig. 4.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 351.

Locality. Maduwari, S. Mahlos Atoll, Maldive Islands; found in the lagoon reef but never seen elsewhere in the Group. It is a widely distributed species, occurring in the Mediterranean and Adriatic and off Norway. Dr Willey collected it at the Loyalty Islands and saw specimens of it in the D'Entrecasteaux Group. It also occurs off the Australian and British New Guinea coasts.

II. Genus THALASSEMA (Gaertner) Lamarck.

2. *Thalassema diaphanes* Sluiter. (Plate VI, fig. 2.)

Shipley. Willey's *Zoological Results*, Part III. 1899, pp. 336 and 346.

A single specimen, 2·5 cm. long, from Hulule. Greatest breadth 8 mm. The animal was curved and the skin of the outer curvature was remarkably thin. The contents of the alimentary canal was in very obvious pellets, as is usually the case in this species. Another bottle containing three specimens from the same locality was labelled "in *Halimeda* masses." Two specimens, one very small, were taken at Minikoi. The smaller was taken "from lagoon sand between the roots of a branching *Porites*," the larger from "sand under stones of reef-flat"; when living this specimen had a proboscis, which when expanded reached a length of 2·7 cm. and its body was nearly as long.

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands. This species has previously been described from the Bay of Batavia and from off Pigeons' Island, New Britain.

As this is the first mention of Hulule I insert here a note drawn up on the spot by Mr Stanley Gardiner on the Echiuroids of that locality:—

"*Thalassema* alone occurs. There seem to be three species, which live in and under the stones of the boulder zone, east and west. A fourth small species—perhaps different—light green colour, rather transparent (*Thalassema diaphanes* A. E. S.)—is found in *Halimeda* masses, but otherwise we have not found any except in the above positions. They are far more numerous to the east. The two specimens of the large species (*Thalassema erythrogrammon* A. E. S.) were obtained under a large stone on sand, close to inside of boulder zone to east. They live quite well for 20 to 30 hours in water in a covered basin, and kill best for museum purposes by very slowly adding dilute Chromic Acid. Alcohol sooner or later causes collapse, however slowly the anaesthesia is performed."

3. *Thalassema erythrogrammon* Max Müller. (Plate VI, fig. 1.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 347.

A single, very large specimen whose dimensions, judging from a life-size sketch made by Mr C. Forster Cooper of the living animal, were:—length of body 39 cm., length of proboscis 11 cm., greatest width of body 4 cm. The posterior end of the body, which is very rugged and pitted, extended some 4 cm. from the extreme end. The specimen preserved in spirit which reached my hands had contracted to about one quarter of the above length. The proboscis, which was extremely contracted and had broken off the body, was but 3 cm. long, and was all bunched up like an acorn in outline.

The colour of the animal differs but little from what has hitherto been described. The ventral surface of the proboscis was yellow with a thin violet stripe as is usual. The fourteen longitudinal muscles were of a purplish red hue with greenish interspaces, and the posterior pitted portion was violet. The animal as Mr Cooper described it "pulsated horribly," and as the contractions passed along the body the areas, which coincided with the point of intersection of the longitudinal and transverse muscles, swelled up into prominent, light-pinkish knobs.

The alimentary canal was full of pieces of coral rock, some of considerable dimensions. Mr J. Stanley Gardiner has been good enough to examine a small specimen of the contents of the intestine and has kindly furnished me with the following list of its varied components:—

"One piece of *Madrepora*, end of a branch, corallum not at all worn down, 13 mm. long by 6·5 mm. in diameter, spines etc. still perfect and cells full of animal tissues: five pieces of *Pocillipora*, the largest 14 × 10 mm.: fragments of *Distichopora*: Lamellibranch and Gastropod shells, two of the latter perfect, apparently having recently contained the living animals: leaves of *Halimeda* and similar Algae in great numbers: Millepore and *Polytrema* fragments: *Calcarina* and other Foraminifera: one Polyzoon fragment: a little bunch of Hydroid remains. The rest of the sample was sand composed mainly of fragments of any of the above.

"The contents appear to indicate that the animal may browse directly on sedentary animals and plants besides taking in sand quite, as it were, passively."

A second specimen from the same locality was too macerated for accurate measurements but it was certainly not smaller than the above.

Locality. Hulule, Male Atoll, Maldive Islands. This is not far from the centre of the known area of distribution of the species, which extends from New Guinea to the Red Sea and as far south as the Isle of Bourbon.

4. *Thalassema moebii* Greef. (Plate VI, figs. 3, 3 *a*, 3 *b*.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 350.

One specimen, 6 cm. long, 1 cm. in diameter. In the living specimen the proboscis was almost as long as the body, but it contracted to one-fifth the body length in dying. The three nephridia were crowded with eggs. Mr Cooper's sketch faithfully reproduces the greyish-yellow passing into violet colour of the animal with its violet stripes running spirally round the body. Another bottle contained six specimens, taken at the same place as the above. This contains a label recording that the specimens were found under stones. A second specimen, from Minikoi, was found "in sand under a loose stone of the boulder zone."

Locality. Hulule, Maldive Islands and Minikoi, Laccadive Islands, also recorded from Mauritius, Upolu and Amboyna.

5. *Thalassema semoni* Fischer. (Plate VI, fig. 4.)

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 351.

A single specimen, 3 cm. long and 7 mm. broad at its broadest. The proboscis much shrunk, but in life as long as the body. The characteristic spiral funnels of the two pairs of nephridia were very evident.

Locality. Hulule, Maldive Islands, also recorded from Amboyna.

6. *Thalassema vegrande* Lampert.

Shipley. Willey's *Zoological Results*, Part III. 1899, p. 352.

Two specimens of this species were taken at Hulule. In many specimens of the Echiuroids collected on this expedition the proboscis had parted from the body but it had always been carefully preserved. In this case there was no trace of proboscis on the animal or loose in the bottle. The specimens were slightly shorter than those hitherto described but the skin seemed much contracted and was not so thin and papery as the latter.

Locality. Hulule, Maldive Islands. This species has also been described from the Philippines and from Rotuma.

EXPLANATION OF PLATE VI.

All the figures represent the life-size of the animals each with its proboscis in a state of moderate expansion. The figures were drawn by Mr C. Forster Cooper and represent the natural colour of the living animals.

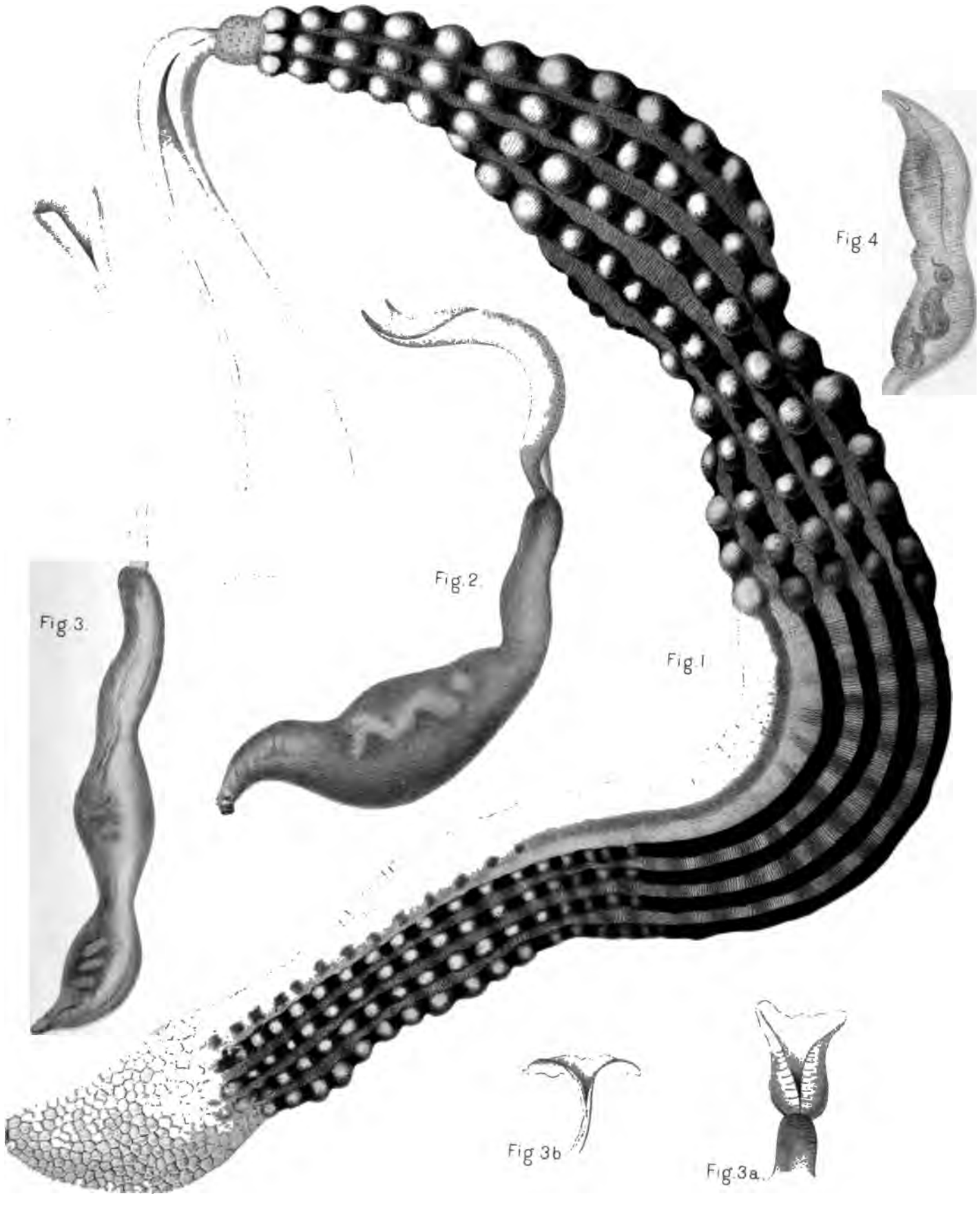
FIG. 1. *Thalassema erythrogrammon* Max Müller.

FIG. 2. *Thalassema diaphanes* Sluiter.

FIG. 3. *Thalassema moebii* Greef. Fig. 3 *a* represents the proboscis of this species when contracted and Fig. 3 *b* represents the tip of the same when expanded.

FIG. 4. *Thalassema semoni* Fischer.

Plate VI



Shipley: Ich. Arbidea.

E. Wilson, Cambr. dg.

SIPUNCULOIDEA,

WITH AN ACCOUNT OF A NEW GENUS LITHACROSIPHON.

By A. E. Shipley, M.A., *Fellow and Tutor of Christ's College, Cambridge, and University Lecturer in the Advanced Morphology of the Invertebrata.*

(With Plate VII.)

The collection of Sipunculoidea brought back from the Maldive and Laccadive Islands by Mr J. Stanley Gardiner's Expedition was a rich one. It comprised the following nineteen species belonging to six different genera, one of which I take to be new, and many species were represented by numerous specimens:—*Aspidosiphon steenstrupii* Dies., *A. truncatus* Kef., *Cloeosiphon aspergillum* Quatrefages, *Lithacrosiphon maldivense*, n. sp., *Phascolosoma dissors* Sel. and de Man, *Phas. lobostomum* Grube, *Physcosoma agassizii* Kef., *Phys. asser* Sel. and de Man, *Phys. dentigerum* Sel. and de Man, *Phys. lacteum* Sluit., *Phys. nigrescens* Kef., *Phys. pacificum* Kef., *Phys. pelma* Sel. and de Man, *Phys. rüppellii* Grube, *Phys. scolops* Sel. and de Man, *Sipunculus billitonensis* Sluit., *S. cumanensis* Kef., *S. indicus* Peters, *S. vastus* Sel. and Bülow. Of these species all but five, *A. truncatus*, *Lith. maldivense*, *Phascolosoma lobostomum*, *Physcosoma lacteum* and *Phys. nigrescens*, were found at Minikoi in the Laccadives and all but four, *Phas. dissors*, *Physcosoma dentigerum*, *Phys. pelma*, and *S. billitonensis*, were found in the Maldives. Thus ten species were common to the two groups of islands.

On the whole the collection bears out the remarks made on the occurrence and distribution of the members of the group in Willey's *Zoological Results*, Part II. 1899, p. 151 and at the end of my paper "On a new species of *Phymosoma*, etc." in *Quarterly Journal of Microscopical Science*, XXXII. 1891.

The account of the new genus will be found at the end of this memoir.

In the following notes on the several species I have not attempted a complete bibliography, but I have mentioned the latest paper available in which the species in question is dealt with. The abbreviations are in all cases those suggested by Dr Sharp in the *Zoological Record*.

I. SYSTEMATIC ACCOUNT.

I. Genus ASPIDOSIPHON Grube.

1. *Aspidosiphon steenstrupii* Dies.

Shipley. Willey's *Zoological Results*, Part II. 1899, p. 153.

Many specimens found by breaking up the coral and stone masses. The specimens varied a good deal in size; the larger examples had the characteristic chalky deposit on the anterior shield.

Locality. Minikoi, Laccadive Islands and Naifaro, Fadifolu Atoll, where it was dredged at a depth of 12—20 fathoms, also recorded from the Philippines, from Mauritius, and from Lifu, Loyalty Islands.

2. *Aspidosiphon truncatus* Kef.

Shipley. Willey's *Zoological Results,* Part II. 1899, p. 154.

A few specimens, all small, were taken at Hulule, Male Atoll.

Locality. Hulule, Male Atoll in the Maldives, also known from Sandal Bay, Loyalty Islands, Mauritius and from Panama.

As this is the first mention of Hulule, Male Atoll, I subjoin some notes made by Mr Stanley Gardiner on the spot with reference to the Sipunculoids of the reefs around that island.

"The Sipunculoidea were not by any means numerous, though a large number of small specimens were obtained from the clumped tops of *Halimeda* masses. A few were taken from some beach-sandstone masses near the village, and a few were secured by breaking up rock masses. A small semi-transparent form was found in sand of the boulder zone occasionally; and two large specimens were in a hole under the rock of the south islet. The "vembol" (*Sipunculus indicus*) is numerous in the sand, but hard to obtain perfect.

"It is remarkable as compared with Minikoi that in the sand under overturned coral masses no Sipunculoids occur, nor under the stones of the spits of the various islands."

II. Genus CLOEOSIPHON Grube.

3. *Cloeosiphon aspergillum* Quatrefages.

Shipley. *P. Zool. Soc. London,* 1898, p. 471.

Numerous examples found living in the coral rocks to a depth of 9 fathoms.

Locality. Minikoi, Laccadive Islands, and from Maradu, Addu Atoll and Hulule, Male Atoll in the Maldives and dredged at a depth of 12—20 fathoms in a passage at Fadifolu in the same islands, previously recorded from many islands in the Pacific and Indian Oceans.

III. Genus LITHACROSIPHON, nov.

4. *Lithacrosiphon maldivense,* n. sp. (*vide* p. 137).

IV. Genus PHASCOLOSOMA S. Str. (F. S. Leuckart) Sel. and de Man.

5. *Phascolosoma dissors* Sel. and de Man.

Selenka. *Die Sipunculiden,* 1883.

Several specimens were found by breaking up the corals and stone masses from the outer reef. These specimens correspond with Selenka and de Man's species *Phas. dissors* in having strongly-bent hooks arranged in numerous rows, large papillae on the body and two retractors. The specimens are however longer than the specimens described by previous

authors, reaching 3 cms. in length, and the relative proportion of breadth to length is different. This latter factor depends however on the state of the contraction of the muscles and must vary from time to time. The retractors are very powerful muscles, and in almost all the specimens collected by Mr Gardiner the body-wall had ruptured and the retractors with part of the viscera had protruded.

Locality. Minikoi, Laccadive Islands. Described also from the West Indies.

6. *Phascolosoma lobostomum* Grube.

W. Fischer. *Abh. Ver. Hamburg,* XIII. 1895, p. 14.

Many specimens of a species which closely corresponds with *Phascolosoma lobostomum* Grube.

Locality. These were dredged at depths between 6 and 20 fathoms at Hulule, Male Atoll, in the Maldives. This species has previously been described by Fischer from Somoa (? Samoa).

V. Genus PHYSCOSOMA.[1]

7. *Physcosoma agassizii* Kef.

Shipley. Willey's *Zoological Results,* Part II. 1899, p. 155.

This species was taken out from the coral rock in which they live.

Locality. Minikoi, Laccadive Islands, Goidu, Goifurfehendu Atoll and from Maduwari, South Mahlos in the Maldives and from Hulule, Male Atoll, in the same Islands. Two specimens found together with the second collection of *S. vastus.* The species, which is very near to *Phys. scolops* Sel. and de Man, has been recorded from the eastern Pacific from Puntarenas to Esquimault, and recently from near the mouth of the Congo, from Ponapé, one of the Carolines, and from Lifu in the Loyalty Islands.

8. *Physcosoma asser* Sel. and de Man.

Shipley. Willey's *Zoological Results,* Part II. 1899, p. 155.

One specimen was found in association with *S. vastus,* and two more under the growing coral at the extreme edge of the reef, where there was no sand.

Locality. Minikoi, Laccadive Islands; a second collection was dredged at a depth of 30—36 fathoms at South Nilandu, in the Maldives, and at 35 fathoms at Kolumadulu, in the Maldives, and at a depth of 40 fathoms at Mulaku in the same Islands. This species extends across the Indian Ocean from New Britain and the Malay Straits to Mozambique.

[1] The following is taken from Dr F. A. Bather's article on Echinoderma in the *Zoological Record,* 1900, pp. 77 and 78. I am indebted to the author for sending me a proof of the article. "*Prophymosoma,* nom. nov. pro '*Phymosoma* Ship[l]ey, récemment proposé pour des Holothuries,' non Haime; LAMBERT (187) p. 54. [*Phymosoma* is not Shipley, but Quatrefages, not a Holothurian but a Gephyrean; the name *Physcosoma* is already proposed for it by Selenka (*Zool. Anz.* XX. p. 460, 1897), but objected to by Spengel (*Zool. Anz.* XXI. p. 50, 1898) because *Physchiosoma* was used by Brera, 1811, presumably in error for *Physcosoma.* But since Selenka gave φύσκων as the derivation of his name, it should have been spelled *Physconosoma,* a form not liable to confusion with any name derivable from φύσκη. *Prophymosoma* is therefore a syn. of *Physconosoma.*]"

The reference to LAMBERT (187) is "Étude sur quelques Echinides de l'Infra-Lias et du Lias," *Bull. Soc. Yonne,* LIII. 1re semestre, pt. 2, Jan. 1900.

9. *Physcosoma dentigerum* Sel. and de Man.

Shipley. *P. Zool. Soc. London*, 1898, p. 471.

A few examples taken from borings in the coral rock.

Locality. Minikoi, Laccadive Islands, also recorded from Funafuti, Rotuma and the Philippines.

10. *Physcosoma lacteum* Sluit.

Sluiter. *Natuurk. Tijdschr. Nederl. Ind.* XLV. 1885, p. 507.

Two specimens which, though I failed to find the area of irregularly scattered hooks intercalated between 80 and 30 complete rows of hooks as described by Sluiter, in other respects seem to belong to this species.

Locality. Hulule, Male Atoll, previously recorded from the Malay Peninsula.

11. *Physcosoma nigrescens* Kef.

Selenka. *Die Sipunculiden*, 1883.

Three examples of this coral-boring form were taken at Inafuri, Goifurfehendu Atoll. It is a variable species, several local varieties having been recorded.

Locality. Inafuri, Goifurfehendu Atoll, also recorded from the Fiji Islands, Funafuti, the Philippines, Mauritius, and the Red Sea.

12. *Physcosoma pacificum* Kef.

Shipley. *P. Zool. Soc. London*, 1898, p. 470 and Willey's *Zoological Results*, Part II. 1899, p. 156.

One example from Minikoi was found under the same conditions as *S. vastus*, and several others were obtained under growing coral masses in the lagoon sand, principally under branching *Porites* and *Madrepora*, also found boring into coral rocks.

Locality. Minikoi, Laccadive Islands, from Hulule, Male Atoll and from Naifaro, Fadifolu Atoll, and from Goidu, Goifurfehendu and from Maradu, Addu Atoll, in the Maldives.

This species extends from the Red Sea through the Indian Ocean to the Pacific. Mr Gardiner had already taken it at Rotuma and Funafuti. Dr Willey found it at Uvea, Loyalty Islands and in Blanche Bay, New Britain.

13. *Physcosoma pelma* Sel. and de Man.

Selenka. *Die Sipunculiden*, 1883.

One specimen, small and difficult to recognize. It was of a dense black colour which must have been due to the action of the preservative reagent, as it is described in Mr Gardiner's notes as transparent when alive. It was found amongst the castings of a large species of *Ptychodera* on the lagoon flat.

Locality. Minikoi, Laccadive Islands.

The species is also recorded from the Philippines, Java and Mauritius.

14. *Physcosoma rüppellii* Grube.

Selenka. *Die Sipunculiden*, 1883.

A few specimens taken out of the coral rock, into which they had bored, at Minikoi and three specimens—also boring forms—taken at Goidu, Goifurfehendu Atoll, in the Maldives. The circular muscles of these had contracted so strongly in the anterior third of the body that the appearance of a very distinct tail was produced such as was described by Lankester in his genus *Golfingia*.

Locality. Minikoi, Laccadive Islands and Goidu, Goifurfehendu Atoll, in the Maldives, previously recorded from the Red Sea.

15. *Physcosoma scolops* Sel. and de Man.

Shipley. *P. Zool. Soc. London*, 1898, p. 470 and Willey's *Zoological Results*, Part II. 1899, p. 156.

The specimens of this species were found in the sand under stones in the boulder zone, most in the large island and at Wiringili; some were taken out of coral masses dredged up from a depth of six or nine fathoms, and others in a passage at Suvadiva Atoll at a depth of twenty fathoms.

Locality. Minikoi, Laccadive Islands, and Suvadiva Atoll in the Maldives.

Like *Phys. pacificum* and *Phys. asser* this species stretches from the Pacific Ocean to the coast of Africa. A few species were found at Minikoi in the same locality as *S. vastus*, *Phys. asser* and *Phys. pacificum*.

VI. Genus SIPUNCULUS L.

16. *Sipunculus billitonensis* Sluiter.

Sluiter. *Natuurk. Tijdschr. Nederl. Ind.* XLV. 1885, p. 487.

Shipley. Willey's *Zoological Results*, Pt. II. 1899, p. 157.

One example only and this differed externally from the specimens, of what I take to be the same species, brought home by Dr Willey. The large black spots were missing, and the anus was not so prominent. The animal was quite 20 cms. long when stretched out. The retractors were inserted very far forward about 3 cms. from the anterior end of the animal, the head of which however was retracted. Thus the proportion of the retractile part of the body to the non-retractile or trunk is much smaller than is usual in the genus.

Locality. Minikoi, Laccadive Islands, also from East Indies and Loyalty Islands.

17. *Sipunculus cumanensis* Kef.

Shipley. Willey's *Zoological Results*, Pt. II. 1899, p. 157.

A large collection of beautifully preserved specimens belonging to Selenka and de Man's variety *vitreus*, many with the introvert and head fully extended. The animals were captured near the south-west end of the Island of Minikoi, where they were found living in the sand under stones. Mr Gardiner notes "these forms are found quite free-living,

but often one or two project from the stones, having apparently taken up their abodes in natural hollows. One can usually see whether they are present or not under a stone, as, if they are, there are considerable sand-castings over and around it. I at first thought that these must be due to some other animal, but found later that, if there is one, there are usually about half-a-dozen under each stone." A further collection was made from "the sand of the lagoon mostly by Wiringili Island" and another belonging to the variety *opacus* from under overhanging, branching *Porites* and *Madrepora*, amongst the lagoon sand. A fourth collection was taken amongst the Maldive Islands, in shallow water at Goidu, another at Hulule, Male Atoll, and yet another collection at Maduwari, South Mahlos, in the Maldives. The body-cavity of one specimen, I opened, was lined by a remarkable fibrous meshwork, which lay inside the longitudinal muscles and seemed tough and resistant.

Locality. Minikoi, Laccadive Islands, and Maduwari, South Mahlos, Hulule, Male Atoll, and Goidu, Goifurfehendu Atoll, Maldive Islands, also recorded from Blanche Bay, New Britain, and the Isle du Phare, Nouméa, from the Philippines and from Venezuela.

18. *Sipunculus indicus* Peters.

Selenka. *Die Sipunculiden*, 1883.

Two specimens, one mutilated and the other 47 cm. in length, from Minikoi, and others from the Maldives. It is described as "living in 'the sand' of the lagoon-flat in long holes open to the surface. It is called by the natives 'vembolu.' The native method of catching them is to push a long thin stick into their holes. This penetrates the body of the animal and by this means the beast is held firm whilst it is being dug out by the hands. It is then by means of the stick turned completely inside out, and in this condition is stuck on a stick and used as bait for day fishing in the lagoon."

Locality. Minikoi, Laccadive Islands, from Hulule, Male Atoll, and from Goidu, Goifurfehendu Atoll, in the Maldives.

The species is recorded from Mozambique.

19. *Sipunculus vastus.* Sel. and Bülow.

Shipley. *P. Zool. Soc. London*, 1898, p. 469 and Willey's *Zoological Results*, Pt. II. 1899, p. 158.

Locality. Several specimens of the variety *albus* were taken "from sand under stones of the boulder zone" at Minikoi, "mostly from the part between the large island and Wiringili." Found together with *Phys. pacificum.* Others were taken from Hulule, Male Atoll, and a few young forms at Naifaro, Fadifolu Atoll.

The species is recorded from Mauritius, Jaluit, Rotuma, Funafuti, Pigeon Island in New Britain, Lifu in the Loyalty Islands, and the Isle of Pines in New Caledonia.

Other specimens of this species were "obtained under upstanding dead coral masses of the outer reef at the base of the beach. These are parts of the solid reef, which have been undermined by tidal action. They are bedded usually in sand rock, which easily disintegrates causing an accumulation of sand in which these forms live. With them Enteropneusta occur in considerable number but never in close proximity. Often under a raised block Sipunculoids alone are found on one side and *Ptychodera* on the other." The

two varieties which in the account of Dr Willey's Sipunculoids I distinguished as *S. vastus albus* and *S. vastus obscurus* were very marked and Mr Gardiner notes that some of the former were translucent whilst others were opaque, a condition possibly depending on the state of the contraction of the muscles. He notes that they take no part "in the disintegration of the rock. It was most noticeable that while the coral masses were bored into by various forms of Sipunculoids, the sand rock everywhere was absolutely free from all living organisms."

II. ON THE NEW GENUS LITHACROSIPHON (Plate VII.).

LITHACROSIPHON nov. gen.

Lithacrosiphon maldivense nov. sp.

A very peculiar form of Sipunculoid was represented in this collection by a single specimen. It was 3 cm. long and averaged about 4 mm. in breadth. The great peculiarity of the animal is that the anterior end of the body is armed with a solid conical cap of hard, calcareous (?) matter. This cap has the shape of the 'sugar-loaf' astrakan hats sometimes worn in Turkestan. The ventral outline of the cap, which runs from the apex to the point where the introvert opens, is straight and in a line with the general surface of the body, but dorsally the surface of the cap slopes down at a sharp angle with the ventral surface to just above the position of the anus. The straight ventral edge of the cap is 3 mm. long, the sloping dorsal edge 5 mm., the width of the cap at its widest, i.e. just where it is inserted into the body, is 3 mm. The cap is borne by a pad of skin, which forms the anterior end of the body, and into which the longitudinal muscles of the body-wall are inserted; this pad is almost transverse to the long axis of the body, but slopes a little from the anteriorly placed orifice of the introvert to the slightly more posteriorly placed anus. The hinder half of the stony cap is of the same deep chestnut colour as the body, and it has the appearance of being covered by a thin extension of the skin, but the anterior pointed half is naked, white and almost glistening.

The cap exhibits a certain laminated structure probably due to lines of growth. If found fossil, it could easily be taken for the end of a belemnite.

The general colour of the animal varies in the specimen, which had been preserved in spirit, from a deep chestnut-brown at the two extremities of the body to a greyish yellow in the middle where the skin becomes sufficiently transparent to show the bundles of longitudinal muscles. Anteriorly the skin, surrounding the base of the cap, is raised up into very numerous tubercles, some of which are arranged somewhat symmetrically round the orifice of the introvert and around the anus. The latter opening is a transverse slit and slightly elevated. The skin is thick and tuberculated for about the anterior sixth of the body, but it gradually thins and loses its tubercles and becomes transparent. In my specimen this is the stoutest part of the body, but outline counts for little in a Sipunculoid. Posteriorly the skin again becomes dark and opaque and covered by brown patches; the skin however hardly thickens, and there is no sign of any posterior shield, such as is so characteristic of the genus *Aspidosiphon*.

The internal anatomy is simple. The introvert in the specimen is fully retracted, and measures from the anterior end to the position of the head about 1 cm. in length. The two

ventral retractor muscles—there are only these two—do not continue to surround the oesophagus, which with the dorsal vessel stand out from the muscles posteriorly. For about half their length the two muscles are fused, but their hinder halves, separated and spread out in a fan-shaped manner, fuse with the fourth to about the twelfth or fourteenth longitudinal muscles counting from the nerve-cord. I was unable to detect any signs of reproductive organs at the base of these muscles.

The longitudinal muscles split and anastomose very freely. In the centre of the body there are some 26—28 strands, but the number diminishes at each end. The circular muscles are also divided into strands and do not form a continuous sheath. Posteriorly there are a number of other small ridges, which cross the skin transversely. These appear to be due to the wrinkling of the peritoneal lining of the skin. A well marked muscle attaches the posterior end of the coiled intestine to the skin.

The nephridia are conspicuous. Their external and internal openings are far forward on the level with the anus or just behind it. They extend over more than half the length of the body, and are slightly crinkled and very uneven in diameter throughout, small irregular swellings being followed by constrictions.

The alimentary canal stands clear of the retractor muscles comparatively soon, though, as fig. 5 shows, anteriorly it is completely surrounded by them. When it leaves them it passes into the thin-walled intestine, which makes some ten or twelve coils. From this the rectum runs first as a fine tube and then as a more capacious one to the anus. As the sections through the oesophagus show, the lining epithelium is ciliated and thrown into ridges, which form as it were the roots of the tentacles.

In the single specimen at my disposal the introvert was completely retracted, and the only way to determine the presence or absence of hooks and the number of tentacles was to cut serial sections through this part of the body. This I proceeded to do, but unfortunately the presence of sand in the introvert materially interfered with the sections until the level of the head was reached.

Hooks are present and in extraordinary numbers. They are arranged in closely adpressed rings, and are compressed against each other so that the bases of contiguous hooks are in contact. Each hook has two points, and the base of each is slightly corrugated. The hooks are but slightly chitinized, very thin and under the microscope appear light yellow. Among the hooks are scattered—I could make out no order—numerous small processes such as are figured on Plate VII. fig. 7, *ch. p.* At first I took these for the bases of the hooks cut across, but on the whole I am inclined to regard them as cuticular products, homologous with but not analogous with the hooks. I have described similar but much larger structures in *Sipunculus australis* Kef.[1], and they probably represent the "zähnchen" of Selenka's Monograph. The number of rings of hooks is unknown; the very short piece of the introvert—about 1 mm.—which I cut contained some forty to fifty rows, and, if they be continued along the introvert, there are probably at least some hundreds.

The mouth is semi-circular and ciliated. Dorsal to it is a small bunch of tentacles, exactly how many I could not make out but should think about eight or ten. The nerves from the brain to these tentacles are very conspicuous. These tentacles are either very

[1] Willey's *Zoological Results*, Part II. 1899, p. 156.

short or very retracted; they form a small lophophore overhanging the mouth dorsally. In section each is roughly triangular, and besides the nerve each is provided with an extension of the blood sinus which lies round the brain. A similar sinus occupies much of the ventral lip, whose margins are, I judge, not broken up into tentacles. These sinuses aid in extending and keeping tense the tentacles and lip, when the introvert is everted.

In the hollow of the lophophore lies a short channel, the "cerebral organ" of Ward[1]. This is shown in Plate VII. fig. 11. It is short and leads to the two eyes.

The brain is compact, slightly hollowed ventrally by the blood sinus which on this surface closely ensheaths it. In the main the ganglion-cells form a dorsal cap. It gives off ventrally the usual circumoesophageal commissures and anteriorly the conspicuous nerves to the tentacles and lower lip.

The eyes are conspicuous, lying on the anterior surface of the brain, where that organ still retains its primitive connection with the ectoderm. Each consists of a cup-shaped pigmented layer of cells, densely black in colour; the little space surrounding the convex side of these cups, seen in Plate VII. fig. 11, is continuous with the cavity of the cerebral organ mentioned above.

The systematic position of this Sipunculoid is a matter of some interest. Its structure resembles that of the genera *Aspidosiphon* and *Cloeosiphon* much more closely than it does that of any other genus, and it resembles *Aspidosiphon* much more nearly than it does *Cloeosiphon*. It however differs from *Aspidosiphon* in the two most important features which characterize that genus. There are no anterior or posterior shields at all, but the anterior shield may perhaps be represented by the pad which bears and secretes the stony cap; if this be so, it may be noticed that this pad is more directly in a plane transverse to the long axis of the body than is that of any *Aspidosiphon* I have ever seen. The animal may be an abnormal form of *Aspidosiphon* but I doubt it. If it represent a true genus, this genus is one of the most easily recognized of all the Sipunculoids, even when the introvert is retracted. In many cases it is not possible at first sight to be sure whether one is dealing with a *Sipunculus*, a *Phascolosoma*, a *Phascolion* or a *Physcosoma*; but no one could make a mistake about this new form. For these reasons I have ventured to establish a new genus although I fully recognize the temerity of such a proceeding when there is only one specimen to deal with. The beginning of the generic name I suggest indicates its stony cap, the end its nearest allies amongst the Sipunculoids.

LITHACROSIPHON nov. gen.

A Sipunculoid with a solid, conical, stony anterior end to its body. The stony cap borne on a pad, and showing traces of a laminated structure. No posterior shield.

LITHACROSIPHON MALDIVENSE nov. sp.

Longitudinal and circular muscles in bundles, the former of 26—28 strands which anastomose freely. Two retractors arising near posterior end. Spindle muscle present. Very numerous rows of slightly chitinized hooks. The hooks in each row two-pointed and very

[1] *Bull. Mus. Harvard*, xxi, 1891, p. 143.

numerous. Intestine in about 10—12 coils, no diverticula on rectum. Tentacles few and short. Two conspicuous eyes.

Locality. The single specimen was procured by breaking up a large coral mass, dredged from 25 fathoms at Miladumadulu in the Maldive Islands. It is worth noting that the undoubted head-quarters of the genus *Aspidosiphon* is in the Indian Ocean.

EXPLANATION OF PLATE VII.

b = brain.
ch. p = chitinous process on introvert.
d. v = dorsal blood vessel.
e = eye.
i = intestine.
int = introvert.
l = base of lophophore.
l. l = lower lip.
n = nerves.
oe = oesophagus.
p = pad which secretes stony cap.
r = rectum.
r. m = retractor muscles.
sp. m = spindle muscle.
v. n = ventral nerve cord.

FIG. 1. Side view of *Lithacrosiphon maldivense* Shipley, × 2, showing the appearance and the colour of the specimen preserved in spirit.

FIG. 2. Dorsal view of the head × 4, showing the white calcareous cap, the sheath which surrounds its base, the tubercles on the skin, and the anus.

FIG. 3. Ventral view of the head × 4, showing the orifice of the introvert and the other structures mentioned under Fig. 2.

FIG. 4. Side view of the head × about 4·5, showing the profile of the calcareous cap.

FIG. 5. The body of the animal laid open by a dorsal incision to show the internal organs, × 2.

FIG. 6. One of the chitinous projections found amongst the hooks of the introvert, highly magnified.

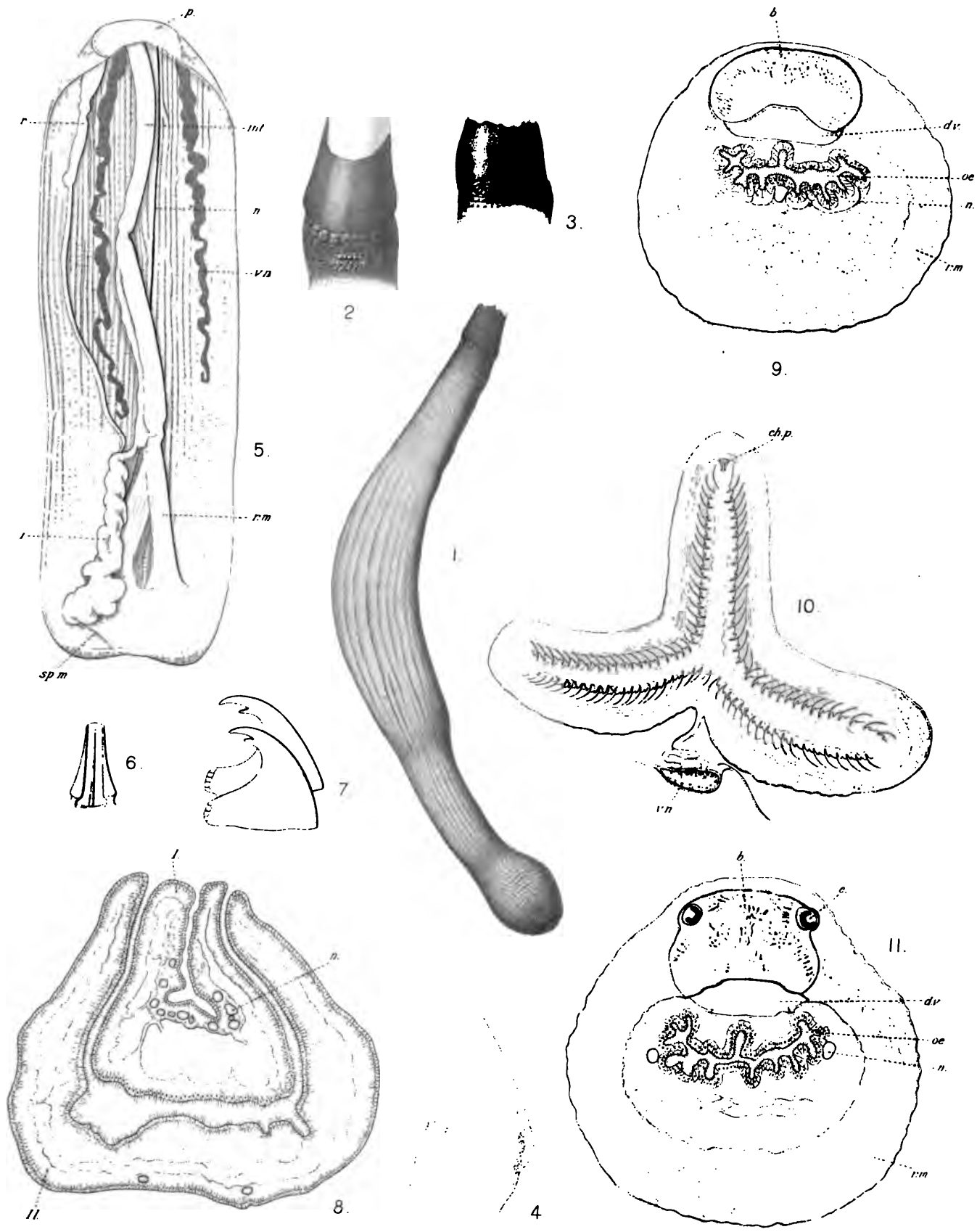
FIG. 7. Two of the hooks of the introvert, highly magnified.

FIG. 8. Transverse section through the semi-circular mouth, showing the base of the lophophore and the lower lip, each with nerves coloured yellow and blood sinuses white, highly magnified.

FIG. 9. Transverse section through the posterior half of the brain and through the ventral half of the circumoesophageal nerve-ring, both coloured yellow.

FIG. 10. Transverse section through the retracted introvert and the ventral nerve cord. The introvert had contracted into a three-ridged tube. The hooks and nervous system are coloured yellow. One of the chitinous projections is shown.

FIG. 11. Transverse section through the anterior half of the brain showing the eyes; the two halves of the circumoesophageal cord are shown on each side of the oesophagus.



Shipley - Sipunculoidea

E. Wilson, Cambridge.

LAND AND FRESHWATER MOLLUSCA.

By Edgar A. Smith.

The small collection obtained by Mr Stanley Gardiner's expedition is of special interest as being the first made in these islands. As far as I can ascertain, not a single land or freshwater shell has hitherto been recorded from these localities.

The present collection comprises eight land and two freshwater forms from the Maldives and four terrestrial species from the Laccadives, three of which are included among those from the Maldives. The latter group, judging from the collection at hand, does not possess a single indigenous species, all the forms occurring either on the Indian Peninsula or in Ceylon or other localities. The single species (*Sitala vagata*), described as new from the Laccadives, will in all probability eventually be found on the mainland of South India.

The following table shows at a glance the distribution of the species recorded:—

	India	Ceylon	Other localities
Succinea vitrea[1]	×		
[2]*Sitala vagata*[3] n. sp.			
Euplecta indica	×		
Xestina bombayana	×		
Rhachis punctatus[1]	×	×	Zanzibar, Mozambique
Opeas gracilis[1]	×	×	Sumatra, Java
[2]*Tornatellina manilensis*			Philippine and Natuna Is.
[2]*Melampus castaneus*			Christmas Is., Samoa, Hawaii.
Leptopomoides halophilus		×	
Melania tuberculata	×	×	Africa, Madagascar, Mauritius, Syria, Persia, Arabia, Siam, Java, Australia, &c.
Cyrena ceylonica		×	

In the "Introduction" to this work (p. 7) Mr Gardiner refers to the introduction of many plants by foreign vessels. Doubtless from time to time communication with the

[1] From both Maldives and Laccadives.
[2] Not yet known from India or Ceylon.
[3] From Laccadives only.

mainland is effected by native craft, which might very easily transport the few molluscs, that occur on the islands.

1. *Succinea vitrea* Pfeiffer.

Succinea vitrea, Pfeiffer, *Monog. Helic.* vol. IV. p. 810; Hanley, *Conch. Ind.* pl. LXVIII. figs. 2, 3; Sowerby, *Conch. Icon.* vol. XVIII. pl. III. fig. 20.

Hab. Fainu, North Mahlos Atoll; also Minikoi, Laccadive Islands.

This species was originally described from the neighbourhood of Calcutta, and it also occurs at Bombay. It is scarcely separable from *S. crassiuscula* Benson, another Indian form.

2. *Sitala vagata* n. sp.

Testa obtuse turbinata, minute perforata, tenuis, dilute fuscescens, lineis incrementi tenuissimis obliquis striata, striisque spiralibus minutis supra et infra sculpta; spira mediocriter elata, ad apicem obtusa; anfractus quinque convexi, regulariter accrescentes, ultimus ad peripheriam acute angulatus, infra convexiusculus, antice haud descendens; apertura oblique lunata; peristoma tenue, margine columellari albo, supra paulo dilatato et reflexo, umbilicum partim obtegente.

Diam. maj. 3 millim., min. 2¾, alt. 2½.

Hab. Minikoi, Laccadive Islands.

The spiral striation is excessively fine and only visible under a strong lens. This species probably occurs on the Indian Peninsula, although I cannot identify it at present with any known Indian form.

3. *Euplecta indica* (Pfeiffer), var. *malabarica*.

Helix indica Pfeiffer: Reeve, *Conch. Icon.* vol. VII. pl. LXXXIII. fig. 448; Hanley, *Conch. Indica*, pl. LV. fig. 10.

Euplecta malabarica n. subsp., Blanford, *Proc. Malac. Soc.* vol. IV. p. 250, pl. XXV. fig. 5.

Hab. Fainu, North Mahlos Atoll (Gardiner); Malabar Coastland (Blanford).

A smaller form than the type of *indica*, with a more conical spire, more convex whorls, and stronger and more granose sculpture. *Helix shipleyi* Pfr. is another variety of this species.

4. *Xestina bombayana* (Grateloup).

Helix bombayana, Grateloup, *Actes Soc. Linn. Bordeaux*, vol. XI. p. 406, pl. I. fig. 1 (1839): Pfeiffer, *Conch. Cab.* p. 327, pl. CXXX. figs. 4—5; Hanley, *Conch. Ind.* pl. XXIX. fig. 5; Deshayes, *Hist. Nat. Moll.* vol. I. p. 181, pl. 69 I, fig. 5.

Helix belangeri, Reeve (non Deshayes), *Conch. Icon.* vol. VII. pl. CCVI. fig. 1457.

Nanina bombayana, Tryon, *Man. Conch.* series 2, vol. II. p. 80, pl. XXIII. fig. 43 (copy of Reeve).

Hab. "Fainu, North Mahlos, also Male, North Male Atoll, but nowhere else in the group" (Gardiner).

The specimens from the above localities agree in all respects with those from the mainland of India, whence they have probably been transported by human agency. In the present species the concentric or spiral striation upon the upper surface is very faint, and scarcely visible to the naked eye. In *X. vitellina* Pfeiffer, which should, I think, be considered a variety, it is rather more distinct. In other respects I can detect no difference.

Helix belangeri Deshayes, united with this species by Blanford[1], appears rather different.

The shell described and figured in the *Voyage aux Indes orientales*, p. 413, pl. I. figs. 1, 2, 3, is almost double the size of average examples of *bombayana* and very different in form. The sculpture upon the upper surface also is finer than in the shell depicted by Deshayes.

5. *Rhachis punctatus* (Anton).

Bulimus punctatus Anton: Reeve, *Conch. Icon.* vol. v. pl. LXV. fig. 452; Pfeiffer, *Conch. Cab.* ed. 2, p. 229, pl. LXII. figs. 22—24; Hanley, *Conch. Ind.* pl. XX. fig. 10.

Hab. Turadu, Heddufuri, Cumfinadu, and Mahdu, all South Mahlos Atoll; Fainu, North Mahlos Atoll; Hulule, North Male Atoll; also Midu, Addu Atoll: Minikoi, Laccadive Islands.

This species is widely distributed in India, being recorded from near Calcutta, Poona, Bombay, Benares, Trichinopoly, Orissa, etc., also Ceylon, Zanzibar and Mozambique.

During aestivation it might easily be transported almost any distance attached to grasses or herbage of any description, hence its wide distribution. The Maldive specimens are quite normal in every respect.

6. *Opeas gracilis* (Hutton).

Bulimus ? gracilis ? Hutton, *J. Asiatic Soc. Bengal*, vol. III. pp. 84, 93 (1834); Reeve, *Conch. Icon.* vol. v. pl. LXIX. fig. 495; Pfeiffer, *Conch. Cab.* ed. 2, p. 79, pl. XXI. figs. 18 and 19; Hanley, *Conch. Ind.* pl. XXIII. fig. 4.

Hab. Heddufuri and Mahdu, South Mahlos Atoll; Fainu, North Mahlos Atoll; Hulule, North Male Atoll; also Midu, Addu Atoll: Minikoi, Laccadive Islands.

Widely distributed in India, Burmah and Ceylon, also recorded from Sumatra, Java and Borneo. The species of *Opeas* and some allied genera are notorious for their wide distribution, and it is evident that they are capable of surviving transportation for long distances. The eggs, imbedded in earth attached to plants, might very easily be carried from place to place.

[1] *Proc. Malac. Soc.* vol. IV. p. 245.

7. *Tornatellina manilensis* Dohrn.

Tornatellina manilensis Dohrn, *Mal. Blätt.* 1863, vol. x. p. 160; Pfeiffer, *Monog. Hel.* vol. vi. p. 264.

T. natunensis Smith, *Ann. Mag. Nat. Hist.* 1894, vol. xiii. p. 458, pl. xvi. fig. 7.

Hab. Hulule, North Male Atoll.

I cannot distinguish the few specimens from the above locality from this Philippine form. Other examples were described from the Natuna Islands under the name of *T. natunensis.*

8. *Melampus castaneus* (Mühlfeldt).

Melampus castaneus Mühlfeldt: Pfeiffer, *Mon. Auric.* p. 30, for synonyms and references; Smith, in British Museum *Monog. Christmas I.* p. 58, pl. viii. fig. 18.

Hab. Inguradu, North Mahlos Atoll, on the shore.

This species occurs at Christmas Island, also the Samoan and Hawaiian Islands—and doubtless in many intervening localities. Other species of *Melampus* also have a very extended range.

9. *Leptopomoides halophilus* (Benson).

Cyclostoma halophilum Benson: Pfeiffer, *Conch. Cab.* ed. 2, p. 241, pl. xxxi. figs. 29—31.

Leptopoma halophilum Reeve, *Conch. Icon.* vol. xiii. pl. viii. fig. 49: Hanley, *Conch. Ind.* pl. cxlii. fig. 4.

Hab. Heddufuri, South Mahlos Atoll; Fainu, North Mahlos Atoll; Midu, Addu Atoll.

A few specimens from the above localities appear to be inseparable from this species. They are smaller than Ceylonese examples and may not be full-grown. Being in fresh condition they exhibit a few spiral lirae, which apparently become worn away or very indistinct with age. Most specimens are of a brownish horn-colour with a single reddish line below the periphery. Occasionally this line is above the periphery, or it may be entirely absent. The Ceylonese specimens are generally of a richer brown colour and inclined to be longitudinally streaked. They also exhibit a pale zone above the infraperipheral line, a feature sometimes observable in the shells from the Maldives.

10. *Melania tuberculata* (Müller).

Melania tuberculata Reeve, *Conch. Icon.* vol. xii. pl. xiii. fig. 87; pl. xvi. fig. 110.

Hab. A freshwater pool, Hulule, North Male Atoll.

Brot[1] gives the following distribution of this well-known species. N.E. and W. Africa, Madagascar, Mauritius, India, Ceylon, Syria, Persia, Mesopotamia, Arabia, Siam, Java. It also occurs in Australia. Only young examples, about 16 mm. in length, were obtained at the Maldives.

[1] *Conch. Cab.* ed. 2, p. 247: also for synonymy and references.

11. *Cyrena ceylonica* (Chemnitz).

Venus ceylonica Chemnitz, *Conch. Cab.* vol. VI. pp. 280, 333, pl. XXXII. fig. 336: Philippi, *Abbild.* vol. III. p. 108, pl. III. fig. 3 (*Cyrena*): Sowerby, *Conch. Icon.* vol. XX. pl. XIX. fig. 111 (*Cyrena*).

Hab. A large freshwater lake, surrounded by mangroves, in the centre of Landu, Miladumadulu Atoll[1].

The species of this genus are generally found near the coast, often buried in the mud of mangrove-swamps. The single specimen from the above locality does not present any characters, which will separate it from the Ceylon form. The outline of most species of *Cyrena* is subject to considerable variation, and as the colour and sculpture of the periostracum are very similar in many of the so-called described species, their identification becomes exceptionally difficult.

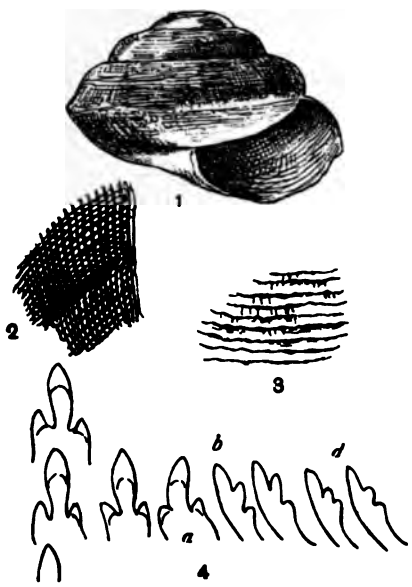


FIG. 24. 1. Shell. 2. Sculpture of upper surface—growth lines 19 to $\frac{1}{100}$ of an inch. 3. Spiral lines on lower surface 9 to $\frac{1}{100}$ of an inch. 4. Radula: *a*. 6th admedian tooth; *b*—*d* laterals.

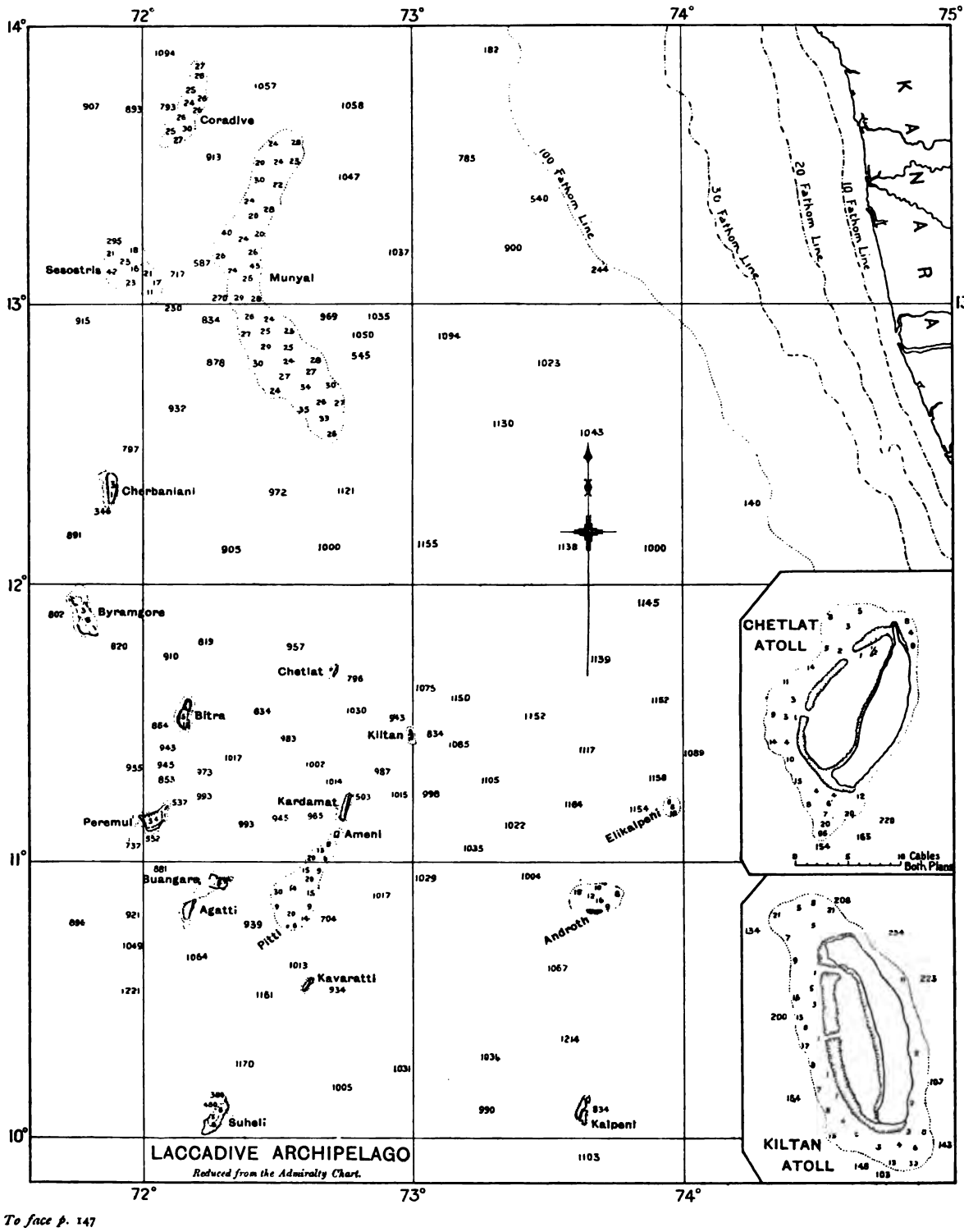
NOTE ON KALIELLA OR SITALA VAGATA.

Since I described this species, Colonel Godwin Austen has kindly examined the radula. He observes—"I have now come to the conclusion that it is nearer to *Kaliella* than any group I know—both in the general form of the teeth and formula,

K. vagata	Type of *Kaliella*
32–6–1–6–32	26–7–17–26
38–1–38	33–1–33

The admedian teeth are all alike, with a long central tooth, with large side cusps, on a quadrate basal plate. The lateral teeth are tricuspid, becoming very minute on the margin. The sculpture of the shell is not as in the typical *Kaliella*, which is finely lirate transversely, but the transition to a decussate or papillate surface cannot count for much."

[1] [The animal is very rarely found, even in this locality. Although similar pools are by no means uncommon in the Maldive Group, the natives elsewhere did not recognize the shell. ED.]


LACCADIVE ARCHIPELAGO
Reduced from the Admiralty Chart.
Coradive
Sesostris
Munyal
Cherbaniani
Byramgore
Chetlat
Bitra
Kiltan
Kardamat
Peremul
Ameni
Elikalpeni
Buangara
Agatti
Pitti
Kavaratti
Androth
Suheli
Kalpeni
100 Fathom Line
30 Fathom Line
20 Fathom Line
10 Fathom Line
KANARA
CHETLAT ATOLL
KILTAN ATOLL
Cables
Both Plans

To face p. 147

of Reef-building Corals and Nullipores—Oceanic Shoals and Deep-Sea Corals —Intermediate depth Corals—Depth of Lagoons—Currents—The Topography of the Banks—The Reef-Platform—Conclusions.

(To be continued.)

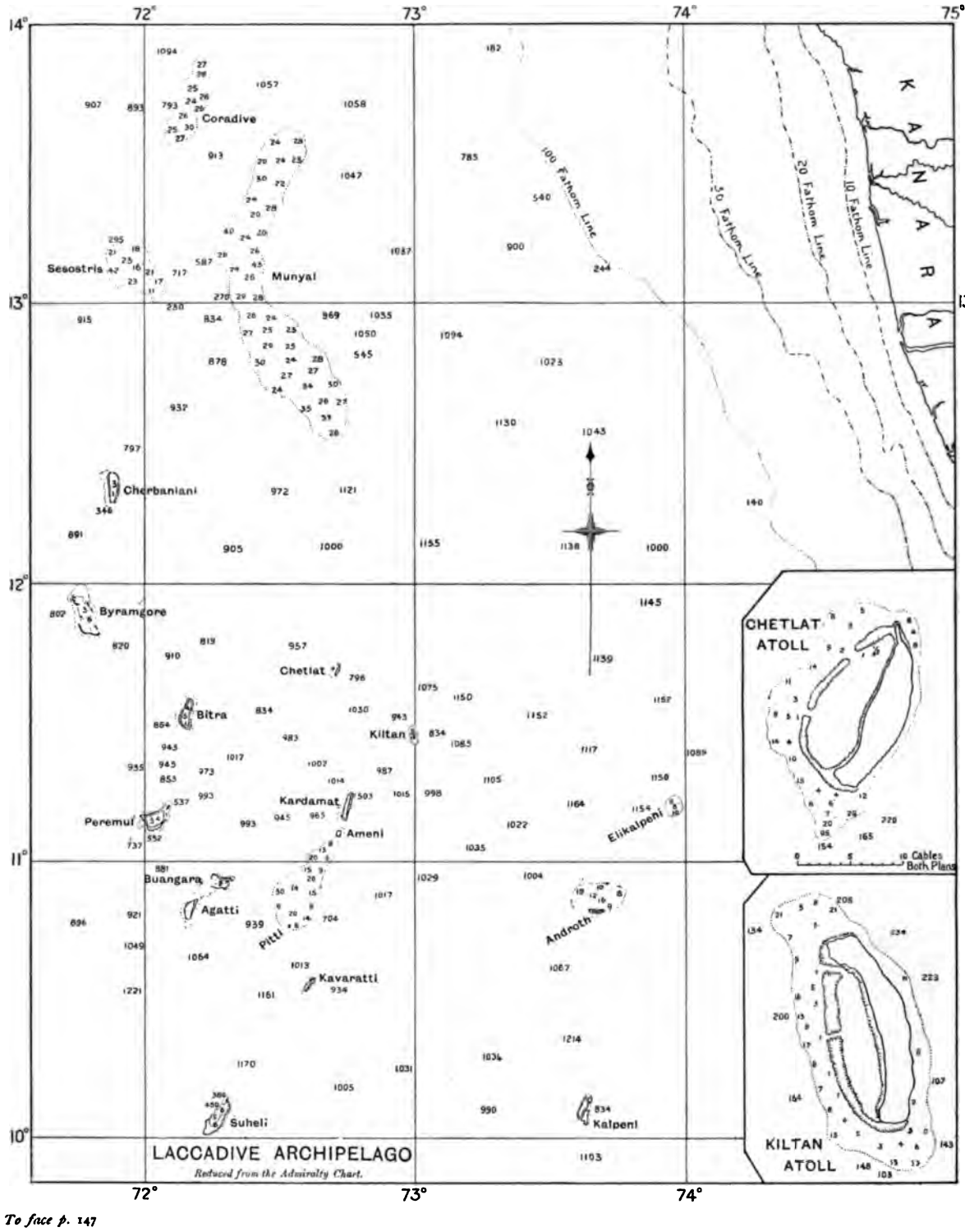
CHAPTER V.

THE MALDIVE AND LACCADIVE ARCHIPELAGOES.

THE Maldive and Laccadive archipelagoes form a long, narrow belt, extending due north and south from the level of the Kanara coast of India in lat. 14° N. to Addu Atoll in lat. 0° 40′ S. (fig. 3). The Laccadives form the north part of the line down to lat. 10° N., and consist of a series of isolated islands and banks, mostly of small size, extending between longs. 71° 40′ and 74° E. The Maldives commence in lat. 7° 10′ N., and then form a definite sequence of large banks between longs. 72° 30′ and 73° 40′ E. Intermediate to the two groups in lat. 8° 20′ N. lies the isolated bank of Minikoi, distant 111 miles from the nearest Laccadive shoal and 71 miles from Ihavandifolu, the most northern Maldive reef. It hence does not belong much more to one archipelago than the other.

The contour lines are not accurately known for the two series of shoals, but it is probable that their common bank has nowhere a greater depth than 1200 fathoms. In the "Nine" and "Eight Degree" Channels on either side of Minikoi soundings of 1195 and 1179 fathoms are recorded, and in the "Equatorial Channel" separating Addu and Suvadiva 1027 fathoms. A bight of deeper water runs up between the bank and the Indian and Ceylon coasts, 1345 fathoms being obtained in lat. 10° N. A depth, however, of 1000 to 1100 fathoms everywhere separates the Laccadives from India, and there is no trace in any part of any connection with the mainland by a series of shoal-patches or otherwise (Plate VIII.). The least depths, 1047, 1037 and 1094 fathoms, are found between the Bassas de Pedro (Munyal) and the coast, distant 117 miles. The breadth between the 100 fathom lines is only 36 miles, and the channel accordingly is comparatively narrow. A possible connection is hence suggested, whereas the narrowness of the channel is really due to the fact that the two archipelagoes lie north and south, while the Western Ghats and the Indian coast extend north-north-west and south-south-east. The channel is further reduced by the increase in the distance of the mud line at about 85 fathoms from south to north along the west coast of India, the regular and customary increase in approaching the head of any bay.

The 2000 fathom line (fig. 3) closely approaches the south coast of Ceylon, and thence runs up slightly towards Cape Comorin. Between the latter and Minikoi the depth is about 1550 fathoms, the 2000 fathom line passing right across to the Maldives, which it probably closely follows southwards at a distance of 30 to 40 miles outside the banks. Off the south of Addu it may be expected to be a little more remote, and thence it extends up nearer to the west side of the Maldives, becoming somewhat more distant from the Laccadives and the Indian coast towards the head of the great bay between India and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Kardamat
Peremul
Ameni
Elikalpeni
Buangara
Agatti
Pitti
Kavaratti
Androth
Suheli
Kalpeni
100 Fathom Line
50 Fathom Line
20 Fathom Line
10 Fathom Line
KANARA
CHETLAT ATOLL
KILTAN ATOLL
10 Cables
Both Plans
72°
73°
74°
75°
14°
13°
12°
11°
10°

To face p. 147

of Reef-building Corals and Nullipores—Oceanic Shoals and Deep-Sea Corals —Intermediate depth Corals—Depth of Lagoons—Currents—The Topography of the Banks—The Reef-Platform—Conclusions.

(*To be continued.*)

CHAPTER V.

THE MALDIVE AND LACCADIVE ARCHIPELAGOES.

THE Maldive and Laccadive archipelagoes form a long, narrow belt, extending due north and south from the level of the Kanara coast of India in lat. 14° N. to Addu Atoll in lat. 0° 40′ S. (fig. 3). The Laccadives form the north part of the line down to lat. 10° N., and consist of a series of isolated islands and banks, mostly of small size, extending between longs. 71° 40′ and 74° E. The Maldives commence in lat. 7° 10′ N., and then form a definite sequence of large banks between longs. 72° 30′ and 73° 40′ E. Intermediate to the two groups in lat. 8° 20′ N. lies the isolated bank of Minikoi, distant 111 miles from the nearest Laccadive shoal and 71 miles from Ihavandifolu, the most northern Maldive reef. It hence does not belong much more to one archipelago than the other.

The contour lines are not accurately known for the two series of shoals, but it is probable that their common bank has nowhere a greater depth than 1200 fathoms. In the "Nine" and "Eight Degree" Channels on either side of Minikoi soundings of 1195 and 1179 fathoms are recorded, and in the "Equatorial Channel" separating Addu and Suvadiva 1027 fathoms. A bight of deeper water runs up between the bank and the Indian and Ceylon coasts, 1345 fathoms being obtained in lat. 10° N. A depth, however, of 1000 to 1100 fathoms everywhere separates the Laccadives from India, and there is no trace in any part of any connection with the mainland by a series of shoal-patches or otherwise (Plate VIII.). The least depths, 1047, 1037 and 1094 fathoms, are found between the Bassas de Pedro (Munyal) and the coast, distant 117 miles. The breadth between the 100 fathom lines is only 36 miles, and the channel accordingly is comparatively narrow. A possible connection is hence suggested, whereas the narrowness of the channel is really due to the fact that the two archipelagoes lie north and south, while the Western Ghats and the Indian coast extend north-north-west and south-south-east. The channel is further reduced by the increase in the distance of the mud line at about 85 fathoms from south to north along the west coast of India, the regular and customary increase in approaching the head of any bay.

The 2000 fathom line (fig. 3) closely approaches the south coast of Ceylon, and thence runs up slightly towards Cape Comorin. Between the latter and Minikoi the depth is about 1550 fathoms, the 2000 fathom line passing right across to the Maldives, which it probably closely follows southwards at a distance of 30 to 40 miles outside the banks. Off the south of Addu it may be expected to be a little more remote, and thence it extends up nearer to the west side of the Maldives, becoming somewhat more distant from the Laccadives and the Indian coast towards the head of the great bay between India and

and Pitti also the coral is visible, and is building up circumscribing reefs. The natives do not visit the northern banks, and so less is known about them. If they were fairly level, they might conceivably be deemed to be washing away, but they vary in depth to such an extent (Munyal 14 in 34 fathoms), that there can be little reasonable doubt but that they too are in places being built up by corals and other organisms to the sea level. Growing coral is very seldom obtained by any sounding apparatus, while decaying coral (which abounds, wherever there is growing coral) is readily secured; hence no reliance can be placed on the recorded presence of the latter, as showing the real character of the bottom in any particular place. A further feature is the very marked steep round all these banks, seeming to be in many places absolutely precipitous. To a less extent the same is a feature of all the Laccadive banks, and is especially noticeable as the fall off some seems to extend from about 25 fathoms to 400 or 500 fathoms, or even more.

II. The Maldive Archipelago. (Plates IX. and X.)

In discussing the question of the formation of the Maldives it is necessary to consider the Archipelago in three main divisions, Addu, Suvadiva, and the main group. The two former differ so greatly both from one another and the remaining banks that they require separate consideration. They are divided by relatively broad channels both from one another and the rest of the group, so that their conditions of wind, rain, and currents are not the same. The changes going on in them differ materially as compared with the other banks, and indeed they would appear almost to have been formed quite independently of the more northern shoals.

Addu (fig. 25) differs from all the other banks of the Maldives and Laccadives in its more perfectly-typical atoll-form. Being 10 miles in maximum length east and west by 6½ miles north and south, its encircling reefs are about 20 miles long, of which at least two-thirds are covered with land. The greatest length from reef to reef of the atoll is at the north end, and on this as base the reefs to the south form a rough semicircle. In this there are two passages to the south and south-east—both with shoals growing up—except for which practically the whole reef is crowned with land, only narrow gaps separating the different islets. To the north the reef runs so as to form a bay, which has at its head two narrow passages; these seem to have been considerably filled up since the survey was made in 1835, and are never now used by the islanders for their vessels. The north reef itself is narrower and almost bare, two islets being found on the patch of reef between the passages, and a few others extending out along the reef for about a mile from Midu at the north-east. The chart has in the lagoon a patch of soundings of 34 to 39 fathoms, but our deepest sounding was only 31 fathoms, and soundings

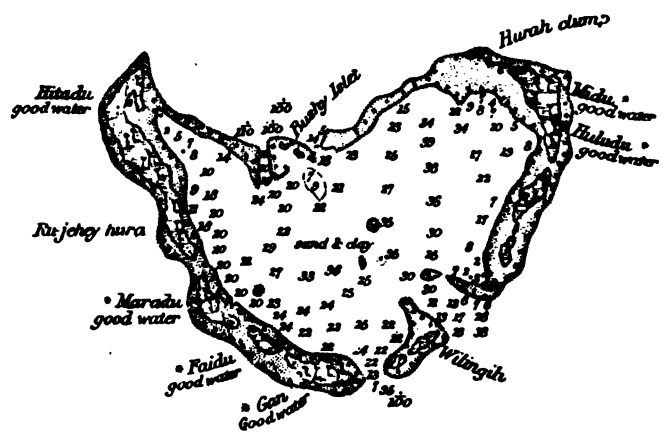


Fig. 25. Addu Atoll (*from the Admiralty Chart*). Scale 4 miles to 1 inch.

patches generally did not, however, appear to have greatly changed in size, but some had subdivided themselves into two or more separate masses. The lagoon islands are undoubtedly all washing away, and none are now inhabited. The majority seemed to be of sand formation, surrounded by rather rocky reef-flats. In the depth of the lagoon our soundings showed an increase varying from 1 to 4 fathoms towards the centre of the atoll, but there did not appear to be any general change near the encircling reefs. The shoals almost uniformly reach the surface, or within 2 or 3 fathoms of the same; they have precipitous walls from about 5 fathoms in depth down to 20 or 25 fathoms, where they tail off in an area covered with rough, dead coral to the general depth of the lagoon in their vicinity. The bottom is in the shallower parts covered with sand, but over the centre and below 40 fathoms with fine mud. It was remarkable that the dredgings nowhere gave any signs of any shoals growing up, the bottom appearing in any one place to be almost a dead level. On the whole the atoll is scarcely at all changed since the survey, and the conditions are such that it is only after a minute examination that any deductions should be actually ventured upon. The atoll has reached an almost perfect state, and is of such extremely large size that it is quite probable that many of the changes, now going on, are quite secondary and not such as are taking place in the majority of atolls[1].

The remainder of the banks of the Maldives form a well-defined line of 325 miles in length without any breaks of really considerable extent. The line is single at either end, but it doubles itself in the centre and encloses a long narrow strip of water between its two series of shoals. There were no soundings in the original survey, which served in any way to show the topography and connections of the central reefs with one another, but we succeeded in running three lines across the basin as follows[2]:

1. Mawafuri, North Nilandu to the channel between Wattaru and Mulaku 157, 164, 176, 188 and 198 fathoms.

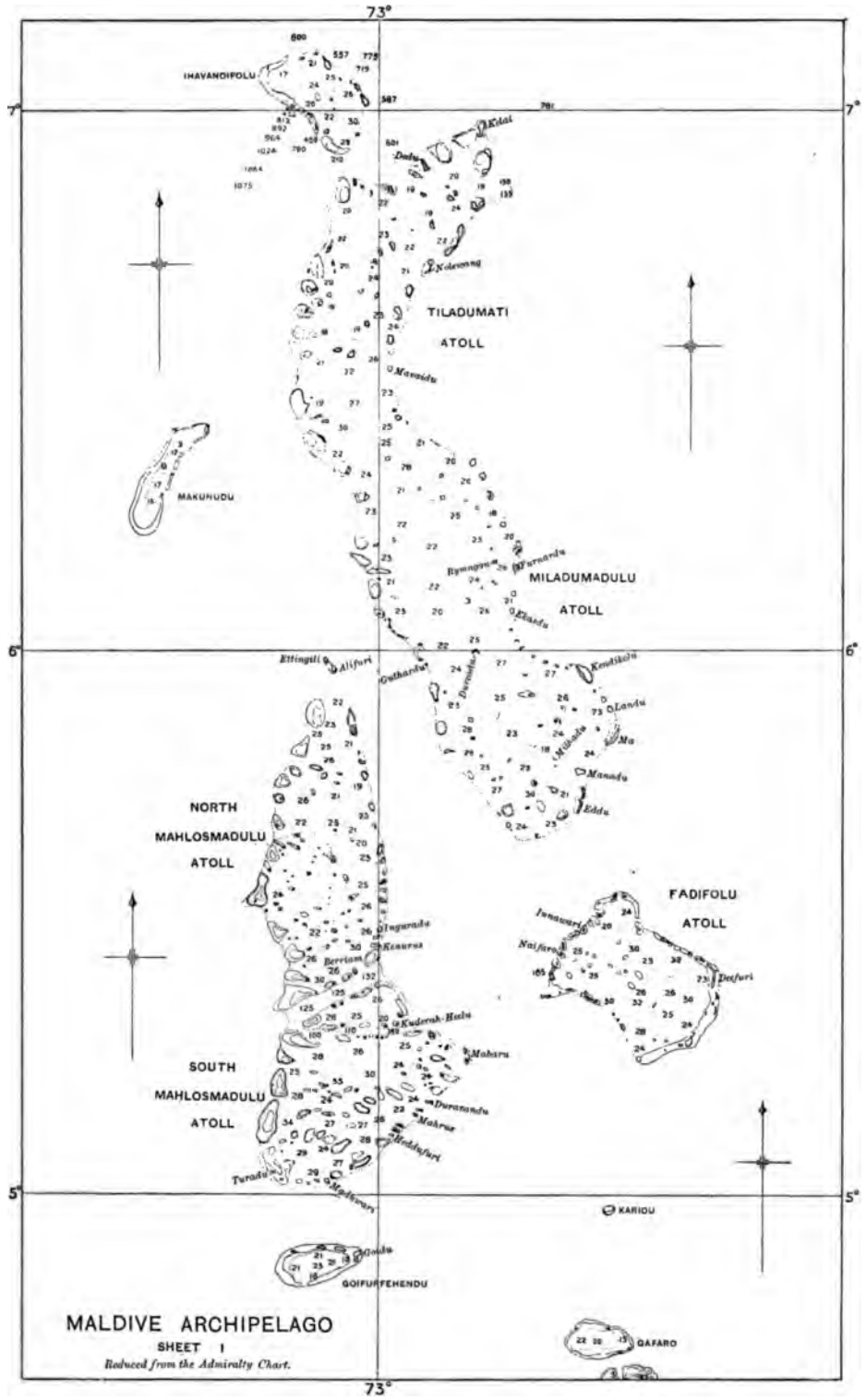
2. Felidu, the first sounding 5 miles and then a line 10 miles north of the last to the channel between North Nilandu and Ari 206, 201, 197 and 198 fathoms.

3. Mahiaddu, Ari diagonally across the basin to the channel between the two Male banks 188, 205, 205, 192, 162 and 186 fathoms.

In addition I ran a section out until a level bottom at about 165 fathoms was reached one mile to the west of Naifaro, Fadifolu, and there are a series of soundings in the chart between Ari and Rasdu and the latter and Toddu, showing a level bottom at about 150 fathoms. We also sounded some of the channels between the different banks, finding maximum depths of 270 fathoms between Kolumadulu and South Nilandu, 235 fathoms South to North Nilandu, 243 fathoms Mulaku to Wattaru, 260 fathoms Wattaru to Felidu, 198 fathoms North Nilandu to Ari (not quite in the centre) and 245 fathoms South to

[1] Throughout the course of the expedition I was assisted in all branches of the work by Mr Forster Cooper, whose observations relating to matters of fact I have in many places incorporated without special acknowledgment. I was greatly assisted in the work in Suvadiva and Addu by Capt. Molony, s.s. "Ileafaee," who paid particular attention to the locating of the various reefs and shoals in their lagoons.

[2] We used for sounding from the s.s. "Ileafaee" between the atolls and on Addu, Suvadiva and Nilandu banks a "Lucas" machine, kindly lent us by the Admiralty, Mr Lucas himself presenting us with 3000 fathoms of wire. The machine was not adapted to receive a belt from the steam-winch, so that the wire had to be hauled in by hand, an especially long and tedious process, as we had no detachable weights. While in the schooner an ordinary sounding line was generally employed, but for boat-work I more frequently used a loosely-spun cod-line with a 3 lb. lead, as recommended by Mr J. Y. Buchanan.


73°
7°
6°
5°
IHAVANDIFOLU
TILADUMATI
ATOLL
MAKUNUDU
MILADUMADULU
ATOLL
NORTH
MAHLOSMADULU
ATOLL
SOUTH
MAHLOSMADULU
ATOLL
FADIFOLU
ATOLL
KARIDU
GOIFURFEHENDU
GAFARO
MALDIVE ARCHIPELAGO
SHEET I
Reduced from the Admiralty Chart.

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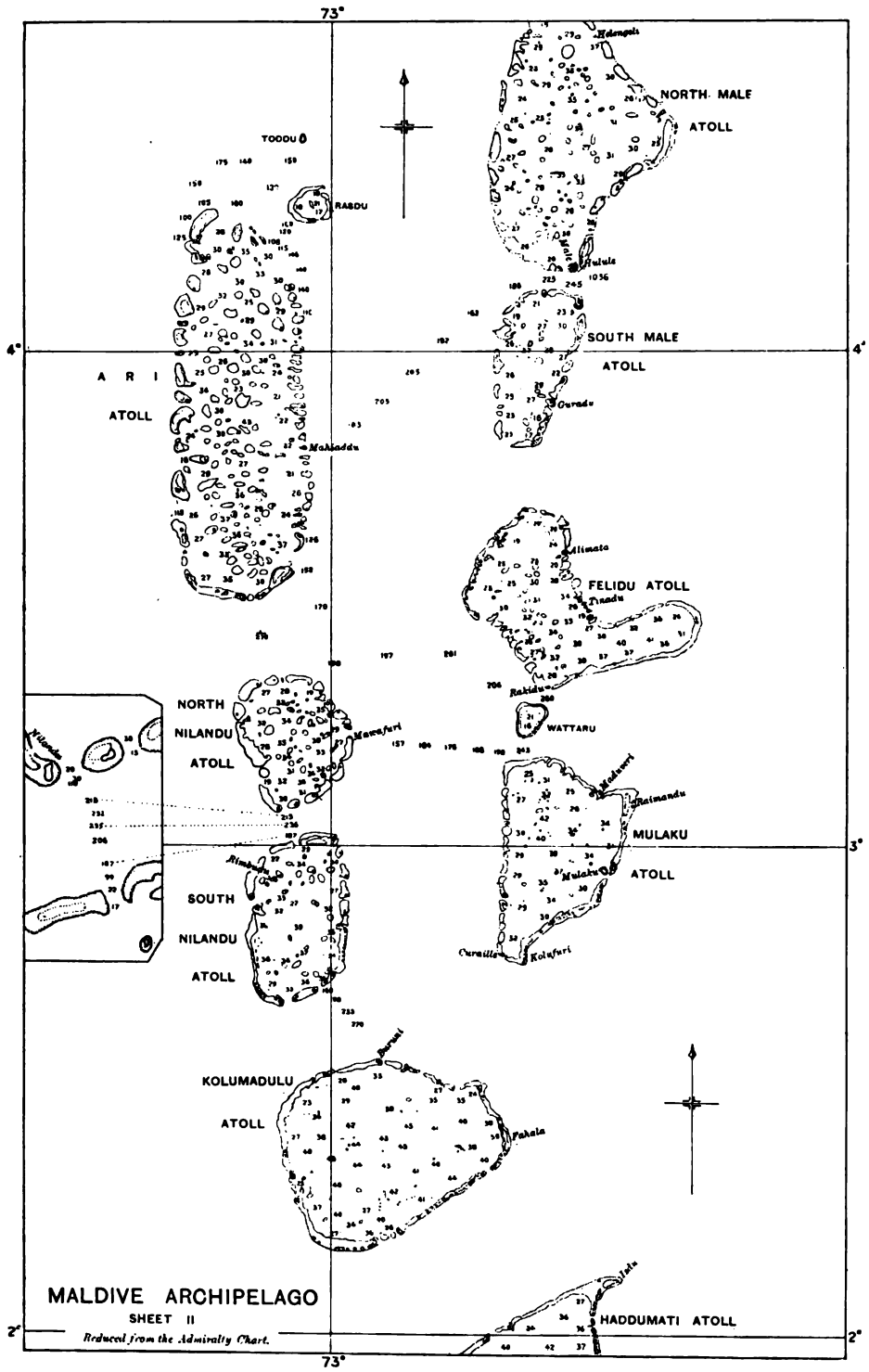

(Showing the lines of soundings run by the Expedition.)

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North Male. In the latter channel we carried the line out eastwards, getting 1030 fathoms two miles south-east of Hulule reef and about the same distance from the nearest reef of South Male. This is the sole sounding off the centre of the group, which at all suggests the contour of the bank as a whole. There may be opposite the passage, where the above

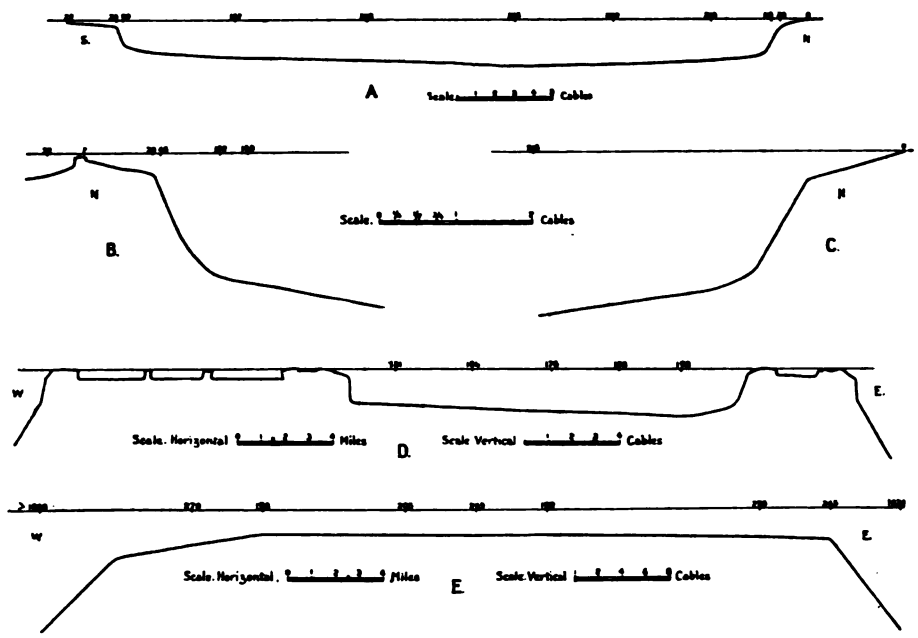


FIG. 26. *A*. Section across the passage between North and South Nilandu atolls. *B*. Section of slope to south of South Nilandu. *C*. Section to south of North Nilandu. *D* and *E*. Sections across the central basin, *D* being supposed to pass across two atolls, and *E* along two of the channels between the banks. (See Plate X.)

sounding was taken, a small bight of deep water, but from the analogy of other reefs it is probable that the 1000 fathom line approaches all the banks nearly as closely on their seaward sides. There are, however, a few soundings to the north, but here the conditions change somewhat owing to the approach towards continental land. A line to the south-west of Ihavandifolu shows a depth of 357 fathoms less than three-quarters of a mile from the reef, a gradual slope to 1000 fathoms at a distance of 5 miles, succeeded by a very much more gradual slope to the 2000 fathom line presumably in a further distance of 30 to 40 miles.

The trend of the Maldives is such that from Kolumadulu to Ihavandifolu it is almost certain that all must lie on the same plateau. The distances separating the banks are inconsiderable save the Kardiva Channel, running north-east and south-west, which between Fadifolu and Gafaro is 27 miles across and between Goifurfehendu and Ari 33 miles. The lines of the banks are, nevertheless, quite clear; indeed on the east side the island of Kardiva breaks the channel almost in the centre, and to the west Toddu stands out about 10 miles north of Ari. There is not improbably a great bight of deep water extending inwards for many miles from the west, and the whole plateau also may be deeper, but at the same time it is unlikely that the banks to the south and north are separated by any depth greatly in excess of that found in the central basin to the south or in the channels

between the atolls. Haddumati to the south and Makunudu to the north-west may arise separately, but Ihavandifolu is almost certainly founded on the same bank, the single sounding, 601 fathoms, in the channel between it and Tiladumati lying considerably to the east of the narrowest part of the passage. The various banks, then, arise as so many plateaus from a common plateau, which has a general depth of about 200 fathoms. This plateau presumably includes on its surface all the banks between Kolumadulu and Ihavandifolu. It probably continues at about the same depth beneath the various banks, to seaward passing into the general slope off the reefs. In the channels, however, as soundings between the two Male atolls show, the depth increases gradually to seaward between the various banks.

In sounding we used the 28 lb. "Valve" leads of Admiralty pattern and the "Snapper," as made by the Telegraphic Construction and Maintenance Co. of Silvertown. The former leads failed on the great plateau to bring up samples of the bottom, and those procured by means of the "Snapper" were very meagre. In the passages between the banks the bottom was evidently extremely hard, only an occasional piece of dead coral being obtained. In the sections across the plateau it was generally similar, with, in places, very coarse sand of broken coral and shell fragments. Fine mud was obtained in the soundings of 205 fathoms due west of South Male, its deposition here being due probably to the protection afforded by that atoll to the east and Ari to the west. The behaviour of the lead in sounding especially in the channels left no doubt but that the current found on the surface extended to the bottom with at least as great force[1].

The banks have to seaward the regular characteristic platform, extending out from the reefs for a distance usually of about 300 yards with a gradual slope to 40 or 50 fathoms. This is followed by the "steep," which at about 150 fathoms passes into a more gradual slope, perhaps the original slope of the whole plateau. This depth though appeared to be very irregular even in a small area, off the south-east of North Male and the north-east of South Male varying between 120 and 180 fathoms. Off North Mahlos, however, the line seemed more regular, lying in three places between 140 and 150 fathoms. Towards the central basin of the plateau the reef-platform is much narrower, seldom exceeding 200 yards in breadth. The steep commences generally below 30 fathoms and the fall then is absolutely precipitous to at least 110 fathoms, the lead not resting anywhere. Of course over such an enormous area the variation in slope may be very large, but the platform appeared to be distinctly narrower and the steep more precipitous against the central basin. In the channels between the banks the platform is usually intermediate in breadth, but the steep commences at a shallower depth than on either side, and is almost perpendicular. In entering North Nilandu from the south the sounding machine near the stern of the s.s. "Ileafaee" recorded 118 fathoms, while the bottom could be seen over the bows of the vessel, a distance of less than 100 feet (fig. 26, *C*). In the Maimbudu passage of South Nilandu also the lead gave 162 fathoms, but when we had got in about 50 fathoms of wire the bows of the steamer drifted over a 6-fathom patch; the lead at the same time stuck in something on the slope and was lost (fig. 26, *B*). Off the south-east of Ari, east of Dungatee the lead hung for a moment at 32 fathoms, and then fell off to 114 fathoms, a fresh sounding a few yards further out giving 126 fathoms. The inner sides of all these atolls may be considered to be their leeward sides, as the force of the waves and currents

[1] When we were sounding in April, the currents were invariably setting from east to west, the wind being from the west and hence opposed to them.

studded with relatively large reefs, themselves usually faro. South Male is very similar but much smaller. Many of the circumscribing reefs are narrower and without velu. Felidu is enclosed by linear reefs or small patches with little velu and narrow passages between. Where the passages are few, the lagoon is almost free from reefs, but where numerous very patchy. Mulaku taken as a whole is still more enclosed, and the lagoon is more open; its shoals are however mostly smaller than in the lagoons of the more northern banks. The circumscribing reefs still have linear velu stretching along them, but they do not at all approach the ring condition.

In the western line Ari is intermediate to some extent between Mahlos and North Male, having a well-defined rim of large faro to the west and south with a series of reef-patches and small faro to the east. A few parts of the lagoon are filled in with small reef-patches, but generally the latter is studded with faro or relatively large reefs. North and South Nilandu have still numerous passages but are more definitely circumscribed by elongated faro than North Male. The north atoll might be placed in the series between North and South Male, the south one between the latter and Felidu. Both have open lagoons with few but relatively large reefs.

The series ends in a typical atoll, Kolumadulu, which save for its greater size, being 26 miles in diameter and covering about 430 square miles, differs in no respect from those found elsewhere in the Pacific and Indian Oceans. It has a long linear circumscribing reef with only 17 passages, most of which are very narrow. The reef itself is in few places more than three-quarters of a mile in width, and, where it is as much, it is either crowned with land or has a pool of deep water in the centre. The lagoon is relatively open, a circumstance due not in any way to a decrease in the number of shoals, but to the latter being of small size, mostly indeed mere patches. Haddumati lastly is very similar, but if possible still more perfect in shape. Its reefs generally are, except where covered with land, narrow with no trace of velu, and there are only six passages, mostly very small, into the lagoon.

A most important point of difference from north to south lies in the gradual increase of the banks in depth, but whether this be correlated with their position or with the perfecting of the atoll-form is not quite clear. The small banks, having relatively a greater amount of reef around them, would naturally be expected to be shallow, as is indeed the case. The large banks admit of a direct comparison, and this shows an irregular increase from Tiladumati to Kolumadulu. In that Ari and the two Nilandu are fairly open banks, and yet have soundings of 36 to 38 fathoms, and the two Male atolls less depths the increase might at first sight seem to be a function of the position. But if Felidu be examined, its greatest depth (41 fathoms) is in the south-east horn, which is almost completely enclosed by reef, while its greatest depths in the northern more open part do not exceed 30 fathoms. Generally indeed in examining all the banks it will be seen that the greatest depths are towards the centre and in the most enclosed parts of the lagoon. It will then be clear that the depth is rather a function of the state of perfection of the atoll-condition than due to the position of the banks. Size is undoubtedly a factor of importance, but the conditions, which govern the depth, are certainly the same as those which give rise to the atoll.

Another notable variation is found in the extent to which land is distributed on the reefs in the centres of the banks. Here again the atoll-condition is probably the determining

factor, but the question is greatly complicated by the fact that the shoals in the circumscribed lagoons are mere small patches of reef, at most a few hundred yards across, while the reefs on the open banks are often a mile or more in diameter. I shall have occasion later, in describing the changes and conditions in North Mahlosmadulu to discuss the meaning of this difference in the size of the interior reefs, but I may here point out that many of the interior islands of the northern banks are situated on the smallest rather than the largest of the lagoon shoals. There are, in fact, even in the most perfect atolls of the Maldives, numerous shoals quite as large as those which support some of the central islands on the open banks. Hence both the smallness of the lagoon shoals and the absence of land would seem to be determined by the atoll-form. In Tiladumati-Miladumadulu there are 65 reefs on the centre of the bank, of which only one has no land. In North Mahlos the percentage, if the "jungle" of reefs in the centre be omitted, would be in favour of those which have land, but in South Mahlos it is the other way. North Male, Ari and the two Nilandu have islands, but they are relatively few in all these banks. South Male and Felidu have islands only near passages or where the banks are open, and there are none in Mulaku, Kolumadulu and Haddumati save one in each atoll, situated right in a passage. Four are known to have existed in Fadifolu of which Moresby found two in 1834; none now occur. The tendency for these islands to exist near passages is important as pointing to the possibility of the currents and general change of water in the lagoons having a determining influence.

Lastly as to the land on the rim-reefs of the banks it is noticeable that it lies rather on the east than the west side in all without determination of their position or form. In Tiladumati-Miladumadulu and North Mahlos every rim-reef of the east side has land, while in the former ten out of thirty-one and in the latter seven out of sixteen on the west side are devoid of such. Fadifolu is to some extent peculiar, but the character is well-marked in all the other banks. It might be pointed out that the strongest and heaviest winds and seas are from the westward rather than the eastward. These might be expected either to pile up coral and so form land, or perhaps, if land already exists, to wash it away. The former supposition is untenable in view of the absence of land, and the latter is largely discounted by the fact that Felidu and Mulaku, which must be to a large extent protected on their west sides by the opposite series of banks, are by far the best examples of the absence of land on the western reefs. The presence of land would seem then to have been determined on the formation of the group.

Each bank, visited by us, in a measure exhibited different changes and conditions, in some one point appearing clearer than in others. It is impossible to give a succinct idea of the extent of the changes and of the varying characters without tracing them particularly, each in the bank which shows it best. North Mahlos[1] however shows most of the points and so may be taken as an example in the next chapter.

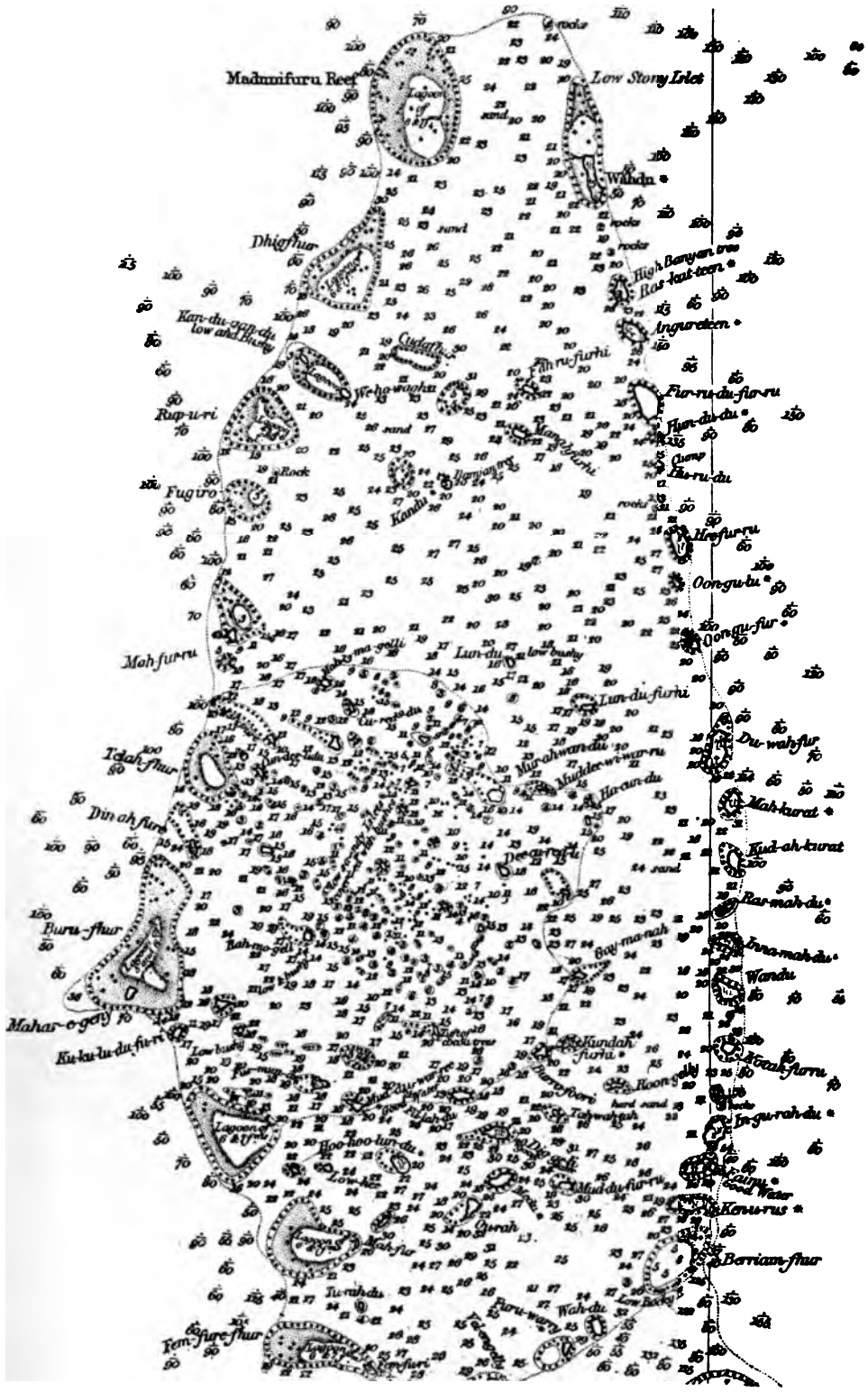
[1] In this bank I visited all the rim-reefs of the western side except the two southern. On the east side I saw Fainu, Kenurus, Inguradu, Raskatteen and Wahdu, most of the rest being visited by Mr Forster Cooper. In addition I crossed the atoll in six levels, and cruised in and out between the central reefs and islands.

CHAPTER VI.

North Mahlos Bank. (Plate XI.)

Mahlosmadulu is divided by deep channels into three banks, each of which has signs of an approaching atoll-condition in series of circumscribing reefs. To the north of the whole bank and separated from it by a deep channel, 2½ miles wide, with no bottom at 100 fathoms, lies a small reef having at its opposite ends the two islands of Ettingili and Alifuri (Plate IX.). The north bank or North Mahlos is 34 miles long by 13 broad in the centre, and extends almost as an oval from north to south. At the south end the Moresby channel, 2 miles broad and 125 fathoms deep, separates it from a central smaller bank, Mid Mahlos, triangular in shape and pointed to the west. This again is separated by a channel of 110 fathoms, less than 1 mile broad, from the South Mahlos bank, 19 miles from north to south by 22 miles from east to west. The three banks from north to south cover areas respectively of about 320, 35 and 270 square miles.

There is no evidence to show clearly whether the three banks of Mahlosmadulu were originally formed as distinct upgrowths, or whether they became disunited from one another as their development proceeded. The probabilities incline to the second alternative, but the point is one which requires to be considered rather in connection with the next chapter. The gross and minute characters of the reefs over the whole Mahlos bank are so uniform, that it is obvious that all must have been formed contemporaneously and are closely connected. The reefs on both sides of the three banks merge into one another in such a manner that any original separation into smaller banks seems impossible. The whole bank would be subjected to the same monsoon currents, which in this position set almost east and west. Moreover—and this is probably of greater importance—the tidal wave which travels along the lines of latitude and extends to the bottom of the ocean, would be resolved into current on meeting a ridge extending north and south such as the Maldives. As the banks grew up on the ridge the rate and hence force of the current would naturally be much accentuated. The two channels in Mahlosmadulu are in the position where this current would act with greatest effect, in that the bank forms a very open bay to the west and there is to the east an inlet, right opposite the deep passage between Miladumadulu and Fadifolu. That the current may be of very considerable force was clear on Nov. 29 and 30, 1899, when after fine, almost calm weather we found it in the deep channels between the three parts of Mahlos varying between 5 and 6 knots per hour. On the following day in the three shallow passages between Inguradu and Berriam-faro the current set constantly to the west, and at no state of the tide was less than 2 to 3 knots. *In accordance with all our experience in the Maldives the current must extend to the bottom*



NORTH MAHLOS BANK

From the Admiralty Chart. Scale 4 miles to 1 inch.

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of these channels with as great force as in the surface waters, and I consider that they have probably been cleared out and owe their origin to this cause.

The general character of the whole bank may be seen by reference to the charts, but after this premiss I return to the consideration of the changes that are going on more particularly in North Mahlos, as also in all parts of the whole Mahlos bank (Plate XI. and fig. 32). Land is found on all the rim reefs of the east side, on some of the central reefs, and a few of the west reefs. The question as to whether this land owes its formation to elevation or to other causes is of great importance in view of Professor Agassiz's work on the coral reefs and islands in various parts of the West Indies and of the Pacific Ocean[1]. The question of elevation and, if found, of its amount can only be discussed in reference to those parts of the land which are formed of coral rock, since sand may be piled up to a considerable height by the wind. No part of the rock at the present day, so far as I have seen in the Maldives, exceeds a height of 12 feet above high tide or 17 feet above the reef-flat, which everywhere shows the approximate level of the low tide. Sand does not, it is true, generally reach as great a height, but here and there dunes are found which greatly exceed it[2]. The island of Maregiri in North Mahlos (fig. 32) is an example, having a general level of 14 to 15 feet above the reef-flat with dunes of 30 feet or more. The whole island, as far as could be seen, is formed of sand with lines of sand-rock in the western beach. It is situated in a whirl of waters, and its reef is fully exposed to the south-west monsoon. The origin of the land in the first place is probably to be traced to the piling up of sand on a flat reef owing to these causes. Some of the dunes were evidently only the formation of the last south-west monsoon, many of the tree-stems being buried for 6 or 7 feet in the sand. Much of the latter will doubtless be levelled down, and spread over the land, but some will remain. A fresh monsoon will heap up more sand in the same places, and in this way permanent mounds will be formed, and the whole island raised in height.

The rim islands of the east and south sides of the whole Mahlos bank have usually at their seaward ends belts or areas of recent coral rock, but this character is much less

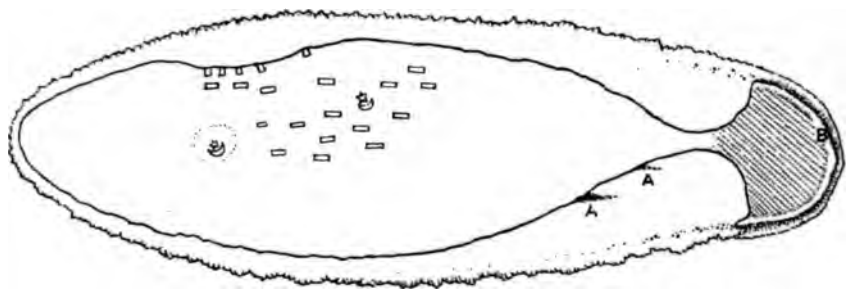

FIG. 27. Kenurus Island. The rocky area of the land is shaded; the sandy area is, as in all these figures, left unshaded. *AA*. Lines of beach-sandstone. *B*. High ridge above the beach formed by piling up of coral-blocks.

marked on the east than the south side. In Kenurus (fig. 27) the east end is formed entirely of coral rock, while the land behind is built up of sand alone. The island is

[1] *Vide* "The Islands and Coral Reefs of Fiji," *Bull. Mus. Comp. Zool. Harvard*, vol. XXXIII. 1899, and numerous other papers.

[2] The question is not complicated, as in the Laccadives, by the artificial hollowing out of the islands for the purpose of forming planting land (*totam*). Among Maldivan people such hollowing out is only doubtfully found in Minikoi, where the race is largely intermingled with the Malabari. *Vide* p. 30.

1¼ miles long by ¼ broad, and lies practically due east and west. It has two bays, one on each side behind the rocky area, which hence is connected by a neck with the rest. The foundation reef round the whole is roughly a narrow oval bluntly pointed at either end. In a section of the east end the reef may be seen to consist of a flat about 26 yards broad, outside which the reef-platform may be distinguished for an additional 150 yards, a very marked point of shallow water extending out seawards. The reef-flat has a very well-defined edge, a broken area with fissures extending in for half its breadth succeeded by an area covered with pinnacles and masses of recent coral limestone, most of which are completely washed by the waves at high tide. The beach behind is steep and reaches a height of about 13 feet above the flat. It is covered with rough masses of coral, which have evidently been separated out on the washing away of the coral rock on the flat outside, recently living coral blocks being practically absent. Limestone masses crop out to a height of 8 or 9 feet, but so far as could be seen all rock above this owed its formation to piling up by the waves. Indeed the latter have built up a ridge right round the east head to a height of 13 or 14 feet, the central part showing a level of 8 to 9 feet. The latter is formed entirely of rock, the surface of which may be quite smooth or covered with jagged coral masses, that have been worn out of the rock beneath by the erosive action of the rain. The reef broadens round both the north and south sides of the head to 40 or 50 yards, and then continues as a well-defined broad flat round the island. The masses and pinnacles are found right round the rocky area, and then continue along the reef-flats on both sides of the land. Round the south side they may be traced for half the length of the island, but on the north the rocks are fewer and do not extend for more than 200 yards west of the rocky area. Where masses are found on the reef at the present day land in all probability formerly existed. According to this view the original island of Kenurus would have been U-shaped, broader at the open base to the west but rounded off and solid at the point to the east. The coral rock can be seen just as decidedly as at Minikoi to have owed its position to a change of level, so that there must have been here a U-shaped reef open to the west. Perhaps the inner part of the U may have been filled in with a sand-flat before elevation, but after the latter change there was a considerable piling up of sand, which extended the land for some distance beyond the open mouth of the original reef. Indeed the west end of the present island of Kenurus is even now growing out into the lagoon by the same means, an eddy due to the meeting of the currents on either side of the reef washing up the sand. The whole beach round the rocky area is washing away, the process being most rapid along its north and south sides. Two lines of beach sand-rock, running out into the water on the south side of the neck, show that the sand once continued out as far as the reef and that the bays were formed on its washing away. Along the rest of the north and south shores there is little or no change, the only washing away being to the south-west. Even there it appeared to be a temporary effect, due to the last south-west monsoon, and seemed on Dec. 2 to be being obliterated by the north-east.

The other islands of the east rim usually have traces at least of the rocky area at their seaward ends in pinnacles and masses of limestone, but whether there is a definite rocky area of the land depends on how far the island is distant from the seaward edge of its reef. Fainu for instance has no rocky area at all, the edge of the reef being about 250 yards from the beach. A zone of pinnacles on the reef to the east and north-east alone shows the former rocky area. The island, however, has at first sight the appearance

of a rocky shore, as the beach south and east is clothed with sandstone. At the east end this runs out into four ridges, two dipping to the north and two to the south, showing periods of rest while the land was being washed away. The method of erosion is plain to the south, where the waves have undermined the rock for 3 or 4 feet. The sea washes up under the masses at low tide with each wave, and has further in many places eaten through the rock above, forming blow-holes which spout after every breaker. A block finally gets broken off, and then is quickly removed. The other sides of the island show loss in fallen coconuts and other timber, and, indeed, the whole island is slowly disappearing now that it has lost its protecting rocks.

Inguradu is intermediate to Fainu and Kenurus, having a small rocky island to the north-east, connected by a ridge of rocks to the main island. The reef off the smaller island is only about 20 yards broad, but off the east end of the main island it is 80 to 100 yards. The beach above it is for the most part covered with loose masses of rock, piled up for a height of 9 to 10 feet above the reef-flat, which itself is covered with pinnacles and masses of the rock. The latter extend round the north and south sides of the island on the reef, and connect with a series of similar rocks in one part of the beach of the west end, which is evidently now washing away. The original reef before elevation would hence appear to have been nearly circular, perhaps partially filled in in the centre with sand.

Indeed every island of the east rim appears to have had at one time a fringe of rocks round its east end, which fringe has been or is now being eroded away. The topography of the present islands depends on how far this fringe continued round on their north and south reefs and on the extent of its erosion in each case. The sandy area behind it was apparently due in some to an elevated sand-flat, but principally to the protection it afforded so as to allow the heaping up of sand by the wind and waves. As a general rule the breadth of the rocky area to the east did not exceed 150 yards, narrowing westwards both along the north and south sides of the reef. Its extensions did not usually meet one another on the west end of the reef, but it has been seen in Inguradu that they closely approached one another. Hurudu (fig. 28) shows a step further, a chart made by Mr Forster Cooper, showing that the island was completely encircled by coral rock. The island before elevation was an almost flat reef at the low tide level—the west end slightly lower—700 yards in diameter with a pool of water of about 4 feet deep in the centre. On elevation the rock began to be washed away on all sides except the west, where some sand was heaped up. In the latter position trees began to grow on the sand, but the sand itself has now been largely removed, and the rock crops out in the base of the beach and forms a line in the land 20 to 60 yards further back. Along the south and south-east sides a coarse beach-rock also has formed of coral and fragments out of the limestone, joined together by carbonate of lime deposited from the sea-water. Wahdu and Berriam are now the only reefs on the east side of the bank that are definite faro (small atolls with lagoons or velu). The former has a rocky island

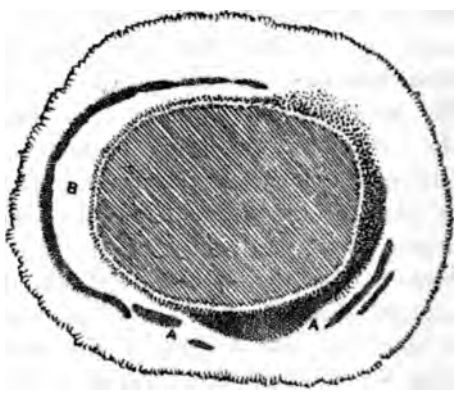

Fig. 28. Hurudu Island. The rocky area of the land is diagonally shaded. *AA*. Lines of coarse coral rock at base of beach. *B*. Sand area. (*From a sketch-map made by Mr Forster Cooper.*)

to the north and a sandy island to the south, with pinnacles along its east side; its lagoon is 8 fathoms deep. The other has a line of rocks along its east and south sides, really elongated islets without vegetation; its lagoon is 5½ fathoms deep.

Of the islets on the reefs of the west rim all are situated towards the inside of the reef and are of sand formation with the exceptions of Cooper Island on the Wa Faro reef (fig. 29) and Kandu-Gandu. In speaking of the former island the natives term it "hura," a name applied to any large mass of rock, standing on a reef, washed over by tides of exceptional height, such as the islands of Berriam. However, Cooper Island (fig. 29) has now become covered with coconut and pandanus trees, shrubs, &c. The method by which the sea has been shut off from it is clear. The waves and tides began to eat into its sides with the result that small masses gradually got broken off and were deposited round the rock as a wall. Between them a little sand found a resting-place, with fragments of pumice, &c. Occasionally at first a higher tide would break through this rampart, and strew its masses over the whole surface of the land for some distance from the sea. Rain action eroded the surface and dissolved out masses of coral, so that the ground even in the centre of the island became covered with loose stones. Sand, further, was blown into the centre, and thus the land was made suitable for plants. The island at the present day is washing away on all sides except perhaps to the east, where a spit of small stones has been heaped up for 336 yards out from the beach; here the waves round the island meet one another and, after forming an eddy, pass on over the reef. The island to the west has now a broad reef-flat with numerous masses of limestone, its inner part against the land forming a rough zone like that to the south-east of Minikoi. South and north the reef has the same characters, but on all sides there is a broad flat outside the outermost pinnacles, the greater part of which has probably been formed by the outgrowth of the reef subsequent to the elevation of the land. The rock also stretched to some degree along the sides of the faro, but there was no heaping up of sand between its horns as on the east side of the bank. The reason of this is probably because of the exposed position of the reef as compared with those of the east rim, and perhaps also to a lesser original height of the rocky area, on this side the limestone being seldom more than 6 feet above the low tide limit.

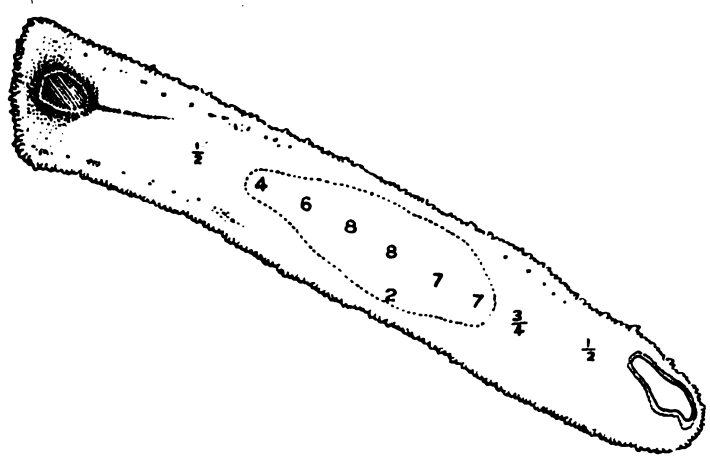

FIG. 29. Wa Faro, showing Cooper Island (rock) to the west and Wa Island (sand) to the south-east. (Soundings in fathoms.)

The limestone throughout North Mahlos is similar to that found at Minikoi, but it has in its composition more sand and broken fragments, fewer large coral masses, and fewer nullipores. *Many of the corals in the limestone being entire and absolutely in the positions in which they were originally growing, there can be no question in respect to the elevation.* The change of level would seem to have been less than at Minikoi by a few

RAISED ROCKS AT MADUWARI

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feet, but it is difficult to decide whether there may not have been more action by rain in North Mahlos. It is possible also that the reef may have been more perfect before elevation at Minikoi than in Mahlos. It has been suggested to me too that the elevation at the two places need not have been contemporaneous, but this view I must absolutely reject. The elevation is found regularly around the tropical belt of the Pacific and Indian Oceans, and has probably not been due to an actual upheaval. It was rather, I think, dependent on a change of level in the ocean, brought about by the attraction of the water towards continental land and to the south polar region. On this view it is quite probable that there may be a real difference in different parts of the Maldives and in the Laccadives. The maximum height of the rock above the reef-flat is 9 feet in Mahlos, but in Miladumadulu it reaches 11 feet, and in Minikoi it is about 13 feet (p. 29). In Hulule, Male atoll, it is only 6 to 7 feet, and in Suvadiva and Addu 5 to 6 feet. Thus there would seem to be a real lessening of elevation to the south. The rainfall, it is true, also increases to the south, and perhaps accounts for some of the difference, but I would still consider that the greater part is really dependent on a less change of level.

It remains now to consider the actual changes of the reefs and land since the change of level took place. In this connection it is necessary to call attention to the much steeper slope for the first 150 fathoms to seaward of the east reefs as compared with that off the west reefs. The character of the latter reefs is the same as those to the west of Minikoi and to the west of Funafuti[1]; the growth of all reef-building organisms—corals and nullipores—extremely vigorous and little or no sand. It is to be remembered also that the east side is protected to some extent by the neighbouring bank of Miladumadulu, the dirt from which must be injurious. The comparison of these reefs is hence with those to the south-east of Minikoi and off the east of the main island of Funafuti atoll. At the same time there can be no doubt, but that all the reefs are growing out on their seaward faces, and it may be assumed that such growth has been general at some time in the past off all the reefs on all sides, independently of any loss or other action that may be going on at the present time. The formation of the sandy areas of the islands may have been partially due to the elevation of flats within the original reefs as already mentioned, but is everywhere, I consider, mainly to be accounted for by the heaping up of sand by the winds and waves. The sand itself varies in coarseness, but none has the muddy character often found in sand-flats, nor could I find in it any traces of worm-tubes, branching nullipores and other organisms, which might be expected to have left some remains.

That some of the original reefs were small faro, before they were elevated, is quite clear from the appearances of Raskateen and Hurudu, but the most striking case in the whole of Mahlos lies in Maduwari, almost its most southerly island (Plate XII. and fig. 30). The reef is about 1¼ miles long at its south or seaward side, the breadth of the bank being rather less. The island lies along the south side of the reef, and to the north of it is a sand-flat with about 4 feet of water at low tide, bounded by a surface reef. The south beach of the island is rocky, with two or three rows of pinnacles on the reef-flat. Above the beach is a rocky belt, which extends around the east and west ends of the island.

[1] *Vide* "The Coral Reefs of Funafuti, Rotuma and Fiji," *Proc. Camb. Phil. Soc.*, vol. IX. pp. 417—503 (1898).

At the west end this belt runs out into a horn, and its continuation is shown by a series of rocks which form a line round the sand-flat, the only open part, never at any time enclosed by such rocks, being to the north-east. The central part of the island is entirely of sand-formation and now washing away. In the past it was clearly formed by the piling up of sand through the north-east opening, a horn now extending in this direction. Between the sand and rock a narrow pool was enclosed, stretching right along the island from east to west, represented now by a mangrove swamp with a pool of water (barachois or kuli) to the west. The line of rocks around the sand-flat is not situated on the reef itself, which is formed of great coral colonies with deep pools and channels of water between, but well within it. The reef is such as is growing up anywhere within the bank, and of recent formation, while these rocks are undoubtedly the remains of the original reef which was elevated. Their foundation is a flat of rock, fairly bare of mud and sand, so that corals may grow on it. The masses stand up to a height of 7 or 8 feet on this. They are formed of coral rock of recent formation, and are undermined and pitted all over. In the drawing (Plate XII.) the end 48 feet of the longest mass (66 feet) is represented; its top is never covered even at the highest tides. Here is an undoubted case of an island having originally been a nearly-closed crescentic reef. Its old lagoon was largely if not completely filled in with sand, but, owing to the erosion of the rocky protective part, most of this has now been removed. The reef has grown out on every side, and a pool is being formed in the centre by solution, the old reef having been dissolved away to a depth of a few feet.

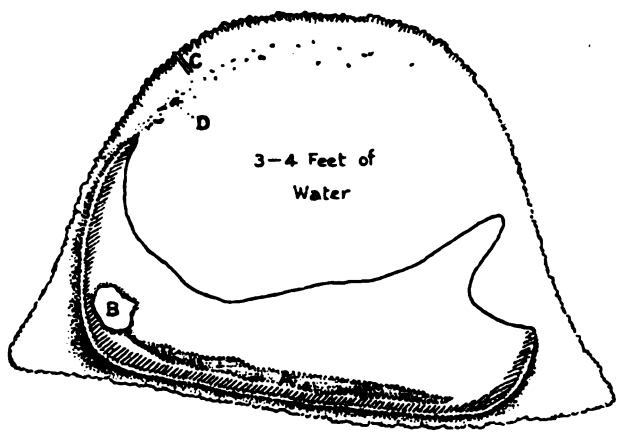

FIG. 30. Maduwari Island and reef. The rocky area is diagonally shaded. *A*. Mangrove swamp. *B*. Pool of water or kuli. *C*. Boat-channel through reef. *D*. Rocks represented in Plate XII.

In North Mahlos there is no case of any island which so strikingly tells its own history, but there are many similar islands and reefs to the east of Miladumadulu. Yet the islands of the east side of North Mahlos show stages in the washing away of the land and the formation of great broad pools between it and the reef. Round Hurudu and Raskateen the reef closely fringes the land. Inguradu has a sand-flat to the north-east, just covered with water at low tide. Kenurus has a broad sand-flat on either side of the neck and a pool to the north-west, each slightly hollowed out below the level of the reef-flat. Fainu has a channel 3 feet deep along the whole of the north side, and off Rasmadu a similar one extends nearly completely round the land. Duwafuri has the channel cut across in places by lines of beach sandstone but otherwise perfect, varying up to 2 fathoms in depth in a pool to the north-west. Wahdu again has a great broad flat to the west with 1 to 2 fathoms or more of water, but this reef shows a much later stage in the presence of a deep velu (8 fathoms) in the centre. Nevertheless only a tendency to form deep pools of water *pari passu* with the washing away of the land is clear.

The changes taking place are better exemplified on the reefs within the bank, where

of nullipores as a factor in their formation may be practically neglected. The importance of these organisms, when present, in welding up the different coral colonies cannot be over-estimated. In effect they act as the ties which keep the whole together, so that it ultimately forms the apparently solid reef. In the case of Mahlos much of the so-called reef-flat round islands may have been part of the original raised limestone, but it is certain that no regular flat is now being formed without the cooperation of nullipores. The inner reefs are mere agglomerations, formed by the growths of various corals, their interstices in some measure filled in by *Halimeda* remains, coral and shell fragments and sand. The corals are bored into by sponges, algae, worms, etc., and killed at their basal ends, so that they are constantly breaking off or collapsing, only to become still more readily the prey of the borers, which riddle them through and through, so that they finally break down into small fragments and sand. The sand-feeding organisms are the last to act on the fragments. Holothurians, Enteropneusts and others swallow them, consuming their organic matter, ultimately to extrude them worn down into still smaller fragments. The carbonate of lime is dissolved and removed by solution, and the silica and other insoluble matters are left as a fine mud or clay. Currents further play their part, and indeed in North Mahlos no clay or mud is found, the whole of the bank being swept almost clean.

The breaking down of the surface of any lagoon reef, together with the coral growth, keeps its appearance almost constant, but the reef is seldom or never still. Its surface-flat is everywhere either growing outwards, or, owing to being broken down and eroded outside, retreating gradually, if the reef be a faro, on its velu. If the foundations for the flat are being built up outside, it naturally extends, but the corals of its inner part are killed by the fine mud, the product of the boring organisms, swept over from outside. A few colonies of *Porites* alone survive for some time, but even these finally go, dying as soon as mud begins to cling to them or silt them up. From the edge of reef-flat of any reef in the more enclosed parts of the lagoon of North Mahlos the bottom falls gradually to 3 or 4 fathoms, and then precipitously to some depth within 7 or 8 fathoms of the bottom in the vicinity. Far more of the coral from the reef above is swept outwards than over the reef and into its velu, if present; indeed the sandy flat, that is found commonly inside such reefs, is generally bare and devoid of fragments of dead corals, save of those few species which may very occasionally be observed growing in such positions. This being the case, it might be expected that these fragments would be swept back over the steep and so gradually extend the reef outwards on all sides. That this is often what happens is quite clear in some parts of Miladumadulu, but it depends on several factors, whether this is generally so in any atoll. The first in importance of these is the circulation of the water, which, if not free, will not remove by solution the excess of carbonate of lime thrown down by the organisms. Further the boring and sand-eating forms, which play a most important part, are not nearly so numerous in open as in enclosed lagoons. An example of such an enclosed bank is Addu, where in the lagoon the reefs are growing up, and sand, formed from them, is gradually raising the level of the bottom. As a contrast Haddumati and Kolumadulu have an ample supply of water, and the interior reefs save near passages have absolutely precipitous sides (on which the lead finds no resting-place) from 2 or 3 fathoms to near the bottom. At the foot of the steep are found masses of dead and decaying coral with a very occasional living colony, but on the steep itself there is no growth of coral nor of other organisms. In an open bank such as Miladumadulu there is no precipice, but merely a steep slope commencing

at 6 to 7 fathoms and seldom exceeding 10 fathoms in height. On it may be seen from the surface masses of *Madrepora*, and dredges and trawls come up off reef after reef, either torn to pieces or nearly full of *Goniopora*, *Alveopora*, *Dendrophyllia* and other corals. Other organisms too are numerous; Alcyonarians and Gorgonians are constantly brought up, and the dead corals from the reef above are protected from solution by Polyzoa, Tunicata, *Polytrema*, and many other incrusting animals. A further character is that, from the edge of the reef-flat to the edge of the steep off such a reef, the whole bottom is covered with a dense grove of corals, while off a reef in Haddumati or an enclosed atoll this area is almost bare save for a few masses of Lobophytum and a little *Halimeda*.

In Mahlos both conditions are found at the present day, that of the enclosed lagoon in the central mass of reefs, and that of the open bank to the north round Limbo-Kandu and the neighbouring reefs. Round the latter reefs the slope is covered with corals and other organisms to a depth of about 6 fathoms, at which depth the steep commences only to fall to about 14 fathoms, being in some places scarcely defined at all. The reefs near Limbo-Kandu are undoubtedly extending outwards on all sides, but it is evident that the above island exercises a by no means helpful influence on its own reef, as the first slope from which the rate of the extension may be judged, is broader off the various faro in the vicinity, and the steep is less marked. In the "giri atiri" or "jungle of reefs" in the centre of North Mahlos the conditions are far otherwise. The steep is everywhere well-defined and the upper slope, until it absolutely passes into the flat, is as described above in closed atolls quite bare of corals. Any corals brought up from the base of the steep are bored into and rotten, and without any protecting organisms. Everything appears to be covered with a thin coat of slimy mud clinging to it, and the reef-flat above is sometimes undermined for a fathom or more. Here and there great masses of the reef have fallen—the sea has not the power within a bank to throw them back on to the reef as negro-heads[1]—and seem to be rotting away. The process is at the same time so slow that it is difficult to prove except by a series of most accurate observations through many years, that any reef is actually washing away, but *the general impression in the "jungle" is that the reef-flat is everywhere being driven back, and that the whole of its reefs are being removed.* I do not see that the characters of its reefs can be otherwise explained, and later I propose to show some definite evidence that there has been loss in the inner reefs of the western faro. The last stage in the history of a disappearing reef is its reduction to a mere little surface patch or series of patches, ultimately single coral heads, which sooner or later will themselves topple over, their basal mounds being subsequently reduced to the level of the floor of the bank. The topographical relations and depths between many of the shoals in the "jungle" show clearly their former connection in single reefs or faro. The last stages it must be remembered are necessarily much slower than the first, as with progressive destruction of the reefs more open conditions prevail, and there is less mud. Even a condition of stable equilibrium may be found, and this I deem to be the case in many of the more open, larger and more perfect atolls. In the smaller such a condition cannot be reached, and hence we find the open lagoons

[1] I restrict the use of the term "negro-heads" to large masses of the rock, which have been broken off the edge of any reef by hurricanes or heavy gales and thrown back on to the reef-flat. I never saw any such in the Maldives, though they were common enough on Fijian and other Pacific Ocean reefs.

of Goifurfehendu, Gafaro and Wattaru. In Fadifolu also there is a very marked destruction of the central reefs, and one even was found to have been resolved into a series of patches.

The reefs against the passages into any bank are subject to strong tidal and other currents, both in and out, which for all practical purposes reach the bottom, the friction being negligible. They hence experience a rapid change of water, which must be advantageous to their organisms, but against this the force of such strong currents and the mud they carry out of the bank must be injurious. Their slope is commonly gradual to about 6 fathoms and then precipitous to within 5 fathoms of the bottom. Where the reef projects as two points on each side of a passage, there is no doubt of what is happening. The edge of each reef is covered with nullipores, which for ever hold each inch they save from the sea. Only a few corals are found, but the slope in such a position in North Mahlos is less precipitous and nearly completely covered with nullipores, as deep as the eye can see. *There is no doubt in many places but that the encircling reef is closing itself up.* That this everywhere is the case in the Maldives, I cannot say, but it seemed to be the rule in every atoll we visited; in many passages we found no change, and in a few a possible compensation in an enhanced depth. Where there is a long passage between two reefs, as between Fainu and Kenurus, the nullipores are only found on the reefs at their seaward ends, and off the latter island there is a distinct shallow horn growing northwards closing the passage. The same is the case north of Inguradu, and Mr Forster Cooper noted it also in several of the other reefs of the east rim. On the west rim I found the channel much restricted between Ma-faro and Kuda-faro, and observed along the whole side the broader western ends of all the faro. Generally speaking, the reefs on either side of passages belong everywhere to the category of outgrowing ones, but it is only the very outer ends of these that can ever meet by the spreading of the reefs themselves. Here again, as the strength of the currents must increase, growth will be less rapid as the rim becomes more perfect. In Mahlos and Miladumadulu the outgrowth of points is quite clear, but in more perfect atolls no definite change could be proved. Even where found, it was never certain that it was a function of the last 60 years, as the tendency of the cartographers would have been to round off every point and reef.

There is also in some of the passages an upgrowth from the bottom, which assists materially in closing them up. In the chart of North Mahlos no less than 10 shoals or reef-patches, that have not quite reached the surface, are marked in the passages. These patches differ from those in the "jungle" in that they are the centres of vigorous organic growth. They are not gaunt rocks but hills, with steep though not precipitous sides, except perhaps towards the lagoon, and are covered all over with corals, nullipores, and other organisms. Of corals *Dendrophyllia*[1] abounds in all the passages, and dead corals are at once covered over with *Polytrema* and Nullipores (*Lithothamnion*). The passages are swept clean of all sand, but some coral must remain. In some of the passages of other banks we found fresh shoals that can hardly have existed before, but we did not examine the

[1] Dr MacMunn in a Report "On the Pigments of *Coenopsammia*, *Dendrophyllia* and *Heliopora*, etc." in the same Part of this Publication points out the presence of chlorophyll among the other pigments and discusses its meaning. Should the chlorophyll assist in the nutrition of the polyps of *Dendrophyllia*, its habitat in the passages should be an exceptionally favourable one owing to the constant change of water. The presence of a chlorophylloid pigment in the skeleton of *Heliopora*—hence completely outside the polyps—is of the greatest interest, and so far as I am aware withou parallel in the animal kingdom.

channels into North Mahlos in view of such[1]. Soundings towards the inner sides of the passages yielded no results on account of the impossibility of comparison, and it was the same within the bank. Indeed, so far as they went, they only served to show that there is little or no change in either position. Bottom samples were never obtained in passages except by the dredge, but elsewhere the "snapper" gave occasional fragments of corals with coarse sand in a few places, the latter only in protected situations or near the centre of the bank. The bottom character generally can only be described in most situations as hard rock, the lead being repeatedly sent down with no result; tallow showed further a clean bottom in such positions.

The comparison of the present condition of the western faro with that of the chart is instructive (Plate XI. and fig. 32). On the whole the topography of Moresby's survey is so accurate that it is evident that the survey was an extremely careful one. From the fact that soundings are given in some of the lagoons and not in others, and that where depths are given from native report it is expressly stated, it is certain that Moresby's officers visited all those whose depths are recorded:—

Maregiri. Sand island with dunes 28 feet high, nearly triangular in shape with base to west-by-south and acute angle to east-by-north, the latter point growing out with no reef, west reef 110 yards broad, north and south 120 yards.

Bodu-faro. Sand island to south, elongated in an east and west direction, equivalent to the north half of the island represented in the Admiralty chart; sand bank covered by a few seedlings to the north-north-east. Lagoon or velu varying up to 12½ fathoms in depth, in size more than twice that shown on the chart, extending far up to the north end and down into the south-west horn. No surface-reef for 1½ to 2 miles along the middle of the east side, but a line of reef at 2 to 6 fathoms, less than 100 yards broad.

Dina-faro. Rock patch to the south of the west end, and sand island to the south-east, rapidly washing away, the north half of the island marked on the chart having disappeared but left traces in lines of beach-sandstone. Small velu, scarcely yet defined.

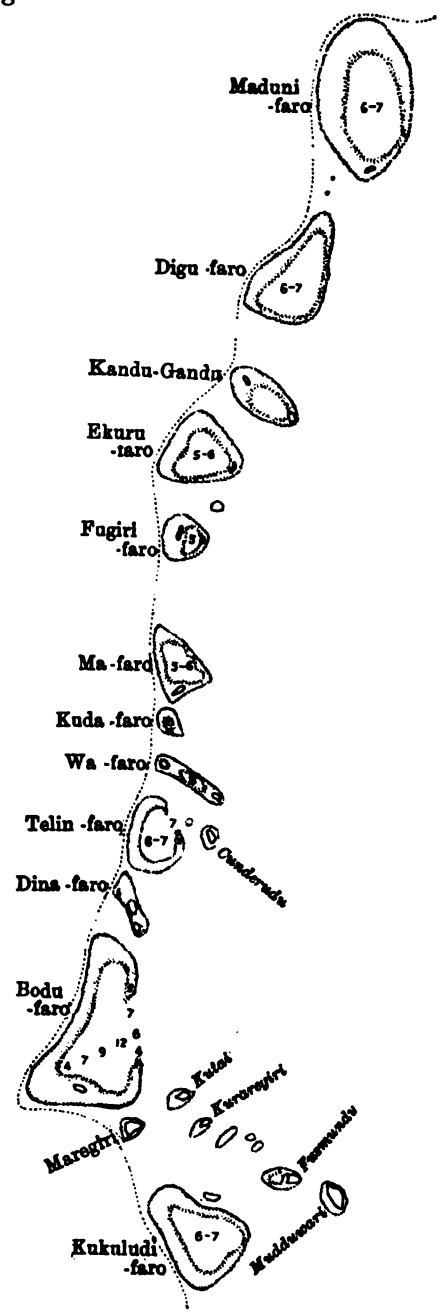

FIG. 32. Reefs of the western rim of North Mahlos, to show the present condition for comparison with Moresby's chart (Plate XI.). *Scale 4 miles to 1 inch, same as Plate XI.*

[1] The winds and currents were so strong during our visit to this bank that it was extremely dangerous to go to leeward (*i.e.* west) of the western faro. I went round Cooper Island in a small boat and took more than two hours in getting through the outer mile of the channel to the south on my return. In the passage south of Maduni-faro there were two points, apparently small reefs occasionally breaking, but the sea was running too high to allow of their examination.

Telin-faro. No islands. Velu 8 fathoms deep, much larger in every direction, the sand-flat and reef to west being about 400 yards broad. Opening into faro north-east, 1 mile broad with depths of 3 to 5 fathoms with in places 7 to 8 fathoms.

Wa-faro (fig. 29). Cooper Island of rock to the west, and Wa of sand to the east, the latter the north half of the island charted. Velu 8 fathoms deep, very well-defined, occupying the centre of the faro.

Kuda-faro. Sand bank on basis of coral rock east-north-east, 60 by 25 yards. Very small velu with 2 fathoms.

Ma-faro. Sand island to south covered with trees, quite inside the reef, the inner part of the island represented. Velu twice the size shown and 6 fathoms deep.

Fugiri-faro. Two small sand banks on west side. Velu somewhat enlarged, 4 to 5 fathoms in depth.

Ekuru-faro. Sand bank to north-east. Velu 5½ fathoms, slightly larger than represented.

Digu-faro. No land. Velu 6 to 7 fathoms, extending up to the north end. Reef otherwise no change, south and east less than 100 yards broad.

Maduni-faro. Sand bank to south and rocks round west side. Velu considerably larger north and west, 7 fathoms deep. Distinct point to the faro running out to the south, reef narrow to the east.

From the above comparison it will be seen that Dina-faro and Wa-faro have now definite velu, while none at all are charted (Plate XI.). Telin-faro and Bodu-faro show that there is a tendency for the different velu to come into communication freely with the general lagoon, and in reference to this point it is important to notice that they are situated against the most enclosed area of the western side. They may, accordingly, be fairly taken as showing the destruction of the reef in enclosed situations. The change in Bodu-faro is a most remarkable one and admits of no possible doubt, as there are in the chart (Plate XI.) on the east side soundings of 18, 15, and 18 fathoms against a reef and sand-flat half a mile broad, where none such now exists. The precipitous slope off these reefs towards the general basin was repeatedly noticed in our cruise, and shows that they tend to wash away on this side. The velu or lagoons have all markedly increased in size at the expense of the sand-flats. The latter are usually bare with less than 1 fathom of water, and at the sides of the velu fall very rapidly to their depths. There may be a few overhanging corals at the edge of any velu, but they are all in the centre bare and covered with sand. There is an ample change of water in them owing to the breakers, which pour over the reefs, and the enlargement of their velu everywhere I can only consider as being due to this cause, acting by means of solution. That this should produce the remarkable increase in depth, about which there can be no question, shows the great effect of the solution and currents, and clearly demonstrates how—starting from a single coral mass, which has grown up to the surface—by lateral extensions a definite atoll may be formed.

I do not wish to claim that North Mahlos alone will serve to demonstrate and much less that it will prove all the different points that I have endeavoured to bring out in this chapter, but I deemed it better to discuss as far as possible one bank alone, and to place in an Appendix an account of the conditions and changes found in other banks. I failed to find any evidence, indeed any indications whatever of any of the reefs of North Mahlos having at any time been joined together. There is no sign of a previous

continuous reef having extended on any side. Indeed no one, who dispassionately considers the fact that the passages are in most cases as deep or deeper than the interior of the bank in their vicinity, can fail to see in this the strongest possible evidence against any such view. *Each large reef on the bank is a separate entity that has grown up and pursued its history by itself, influenced it is true by the reefs in its vicinity but never directly connected with them. It is only now that the bank is at all approaching the condition of the perfect atoll. Having seen how small faro may be formed from their earliest beginnings, we now see in North Mahlos the further fortune of such atolls, their joining together where possible to form long linear reefs with the loss perhaps of the whole inner part of their own reefs.* We find too in Mahlos different physical conditions, and the consideration of its reefs in different parts shows how they are affected, and points to some of the factors that must have been of importance in forming the lagoons of our perfect atolls. The bank, on which these reefs have been built up, was at some former time a plateau at a depth apparently of not more than 30 fathoms, and there must have been on its outer edge a special tendency of growth to have formed its existing series of reefs. When I say that it was a plateau, I am perhaps neglecting the "jungle of reefs" that is found in its centre. There is here a distinct decrease in the general depth of our bank, which from side to side in this situation would appear to have been dome-shaped. This "jungle" is, so far as I am aware, without parallel on any other coral bank of the Pacific or Indian Oceans, and is, I consider, entirely a local feature, complicating our problem. The history of the bank as a whole has been further confused by the elevation of some land, the wash from which must have profoundly affected the reefs round it and retarded their formation and growth. *That any rocky land has been formed save by this change of level is so far as I can see impossible, but many islets in the centre of the group have indubitably been washed up as sand-banks. With other larger sandy islands the origin is less clear, but it is singular that they all show erosion of their shores and some an extraordinary loss.* With the growing up of the rim the eddies and currents must be constantly profoundly changed, and it is to this that some islands owed their origin as perhaps they now owe their erosion. The differences between the east and west sides of the bank must be mainly due to the difference in force of the monsoons on the two sides. In the first place the stronger and more regular wash on the west as compared with the east side would tend to make its reefs larger and more defined. All these reefs had land, where rock masses are now found. This was much more rapidly washed away on the west than the east side. And, lastly, whereas the reef-platform is very narrow on the east side, it has on the west the regular slope off oceanic reefs. However interesting these considerations relating to the land may be, they nevertheless do not affect the general conclusions as to the growth and formation of atolls, of the which for further evidence I must refer to the Appendix.

CHAPTER VII.

The Formation of the Maldives and Laccadives.

In Chapter V. I indicated that our soundings showed that the main chain of the Maldive group lies on a relatively shallow plateau at a depth of about 200 fathoms. The chief problem that concerns us relates to the formation of this bank. There can be but little doubt that it is surrounded with precipitous walls or a steep slope for an additional 600 fathoms at least. Further there is indubitably a close connection between all the various banks of the Maldives and Laccadives, so that they would appear to have been built on the same set of foundations. Any explanation of the formation of one bank, then, must necessarily embrace those of all the others.

The topography of the central deep plateau appears to me to almost preclude the idea that it was formed on the subsidence of a large central island. There is no trace of any such movement continuing to the present day, the only recent change being that which formed the land, a change which must have been one of elevation if it was not due to an alteration in the level of the sea. Under the subsidence theory the existing reef-banks around the central basin would have owed their origin to the direct upgrowth of the fringing and at a later time the barrier reef of this central island. The various reef-banks would according to this view have been formed on the breaking up of the original reef, and the channels between the banks would represent its passages. Where there are a series of the latter opening into the lagoon of an atoll or barrier reef, the majority of such channels have depths less than that of the central lagoon. Indeed it is extremely rare for any of them to equal in depth the lagoon, into which they give entrance. It might hence reasonably be expected that some trace of the original reef would be found in the channels between the larger banks in decreased depths, but this is not the case. The shallower water lies in the centre of the plateau and the depth gradually increases in the passages. Again the peculiarly open condition of the central basin between the banks is of importance in respect to this same question. Either the land must be supposed to have been of extremely uniform height so that there were no eminences in the centre, on which reefs would have built up, or it must be maintained that the present banks represent the positions of the peaks of the land, and that the original land, owing to too rapid subsidence, failed to acquire a continuous reef. Under the latter conditions it would be probable that the valleys separating the mountains along the two chains would be of less depth than the great central valley, a second position which is not supported in any way by the soundings. Indeed it is largely a question of suppositions, and in the case of the Maldives there are required a series so great and complex as to afford strong presumptive evidence against the view that the present reefs are in any way the continuations

of older barrier and perhaps fringing reefs. The original land would have to be regarded as a great plateau, which has sunk to or beyond its present depth. Even allowing that the average level of the whole plateau may have been considerably raised by any valleys having been filled in, it is surely remarkable that on a land site of 330 miles long by 70 broad, an area of about 12000 square miles, no single peak should have continued to exist to the present time. The subsidence theory, further, is absolutely incapable of affording any adequate explanation of the presence within the limit of the Maldive and Laccadive groups of such large atolls as Suvadiva and Kolumadulu, small atolls as Addu and Minikoi, open banks as Tiladumati and Mahlos, isolated reefs as Fua-Mulaku and Toddu, and finally submerged dome-shaped or flat banks as found in the north of the Laccadives.

The banks facing the central plateau drop almost precipitously to its level. It would seem hence that they were erected on it as their foundation, so that it will be necessary first to consider its formation. Two possibilities suggest themselves. The first is by direct upward growth on a deeper plateau, mound or series of mounds on the sea-floor, both by the agency of corals and sediment. This view I shall have occasion later on to discuss in some detail, but I must provisionally reject it here as affording in any way a sufficient explanation of the formation of such a great bank as our central plateau to a height of at deepest 200 fathoms from the surface. The second possibility lies in the cutting down of land above or below the sea by aerial, wave, current and tidal actions to such a depth, the detritus being supposed to have spread out and formed the plateau. First it is necessary to consider what evidence there is as to the depths to which currents extend and at which they, assisted by waves and tide, can move matter. There is very little doubt, but that currents may extend to considerable depths and sweep the ocean floor quite bare. Indeed wherever in the ocean a rocky bottom is found, its character is probably due to an ocean current. To quote Mr J. Y. Buchanan, "when the rocky bottom of the ocean comes up to moderate depths as in the oceanic shoals which I had the opportunity of examining in the s.s. Dacia in 1883, these currents and the tidal element in them are very evident. In archipelagoes like the Canary Islands, which are separated by channels having often a minimum depth of 1200 fathoms and more, the crests of these ridges are swept bare of sediment, and are hard rock, generally calcareous and manganiferous[1]." There is hence no inherent improbability in the original land or bank of the Maldives being cut down to a depth of 150 or even 200 fathoms. The position of the group too would be one eminently favourable to the action of the currents, the plateau rising abruptly and lying right in the middle of the Indian Ocean, fully exposed to the two monsoons. The tidal wave sweeps across the ocean along the lines of latitude, extending from the surface to the greatest depths. Meeting an obstruction, lying absolutely at right angles to its course and extending from the bottom at 2200 fathoms to within less than 200 fathoms of the surface, its energy would be dissipated in current which would be of such force that it alone would probably be quite sufficient to cause the washing down of the bank to its present depth. With such a current there certainly could not be in any case much deposition of sediment on so shoal a ridge. The general hard bottom found in our soundings can only be explained by the action of the currents, and on them lies, I consider, the solution of the question as to the formation of the foundations of the atolls and banks of the Maldives.

[1] "A Retrospect of Oceanography." *Report International Geogr. Congress*, London, 1895, p. 25. I may take this opportunity of expressing my indebtedness to Mr Buchanan for discussing this matter with me.

It is quite unnecessary to repeat the evidence and well-known views of Sir John Murray[1] and Admiral Sir W. L. Wharton[2] as to the action of marine currents in cutting down land and moving matter. Even by continental land where the action is that of currents due to the waves meeting an impediment, the shore platform tails commonly at 80 to 100 fathoms off in a steep, the product of the backwash (see Plate VIII.). That the currents are strong and extend to considerable depths is evident from my being able to accurately note their directions down to 150 fathoms off the reefs. It was quite evident too in my soundings that the current was nearly equally strong in the passages right down to the bottom[3].

Of what rock the original land or bank was formed is entirely a matter of theory and a question, to which the geological study of the Indian continent has so far yielded no clue. It may have been a series of volcanic erupted masses as Sir John Murray suggested. If one supposes that the eruptions were submarine, that in effect the mountains were chiefly masses of loose volcanic matter, it would be easy to imagine even a greater erosion than to 150 or 200 fathoms. Sir John Murray considers that all oceanic islands are volcanic, regarding all others such as New Zealand, Madagascar and Seychelles as continental lands. Yet I may point out that with regard to most groups of coral islands there is no direct evidence to show that their foundations are volcanic. If they are really so, as the mountains of volcanic chains vary greatly in height, there would, it is reasonable to suppose, be a stray peak or two—central cores of hard lava round the craters—still remaining in the Maldives and Chagos. Further, so far as the Maldives are concerned there is no trace of any corresponding activity in the Indian Peninsula. I am hence rather inclined to believe that there was a connection with the other banks towards Madagascar, in fact that these reefs show the positions of the mountains of a great continental land, which once joined Ceylon and Madagascar, but the greater part of which has in past time subsided to great depths and left no trace at the present day. The existence of such a land in the past too is absolutely required to explain the distribution of both animals and plants[4]. The current action would be, I consider, quite sufficiently powerful, aided in the first place by the disintegration of any subaerial land by heat, rain and other agencies, to cut down such a mountainous area, as I suppose to have existed, to the present level of our great Maldive plateau.

It may be contended and perhaps truly that the separate banks are the remains of some of the peaks; that Kolumadulu and Male perhaps were the sites of mountains, which were cut down to a depth of 20, 40 or even 60 fathoms, and then built up by the reef-organisms to their present levels. I can scarcely regard this as probable on account of the great regularity of the common plateau and the regular precipitous slopes of the several banks on all sides. As already mentioned, there is no trace either of a central deeper valley nor of shallower valleys between the separate banks, the plateau being a

[1] *Proc. Roy. Soc. Edin.*, vol. x., p. 507 et seq.

[2] *Nature*, vol. LV. p. 390.

[3] My friend Mr Cameron points out that the influence of the friction of the bottom on the tidal waves and currents may be neglected. Horace Lamb (*Hydrodynamics*, p. 543, 1893), after discussing the viscosity in periodic tidal force, summarised the matter as follows:—"This indicates how utterly insensible must be the direct action of viscosity on oceanic tides. There can be no doubt that the dissipation of energy by tidal friction takes place mainly through the eddying motion produced by the exaggeration of tidal currents in shallow water."

[4] *Vide* "The Anniversary Address to the Geological Society of London" by W. T. Blanford, F.R.S., February 21, 1890, pp. 58—69. It will be observed that, while rejecting the subsidence theory of Darwin as quite inadequate, I consider that the topographical conditions which made the formation of the coral reefs of this region possible, have probably owed their initiation to the sinking of a great continental land.

mound slightly domed in the centre and sloping outwards on all sides. The chief currents from west and east striking approximately in the centre of the plateau, the banks would not naturally be expected to have their long axes lying about north and south but rather more in the direction of the currents. This would of course largely depend on the topography of the original mountains, but the currents, having to cross the bank somehow, would on either side of the valleys at any rate tend to spread out the detritus from the land or bank and to broaden the north and south ends of the shoals in an east and west direction, a condition of which there is no trace in their present contours save perhaps in Felidu alone. Yet at the same time it is quite reasonable to suppose that the banks commenced to grow up before the channels between them attained their present depths. There may even have been a slight additional lowering of the plateau as a whole in depth. The washing away would naturally be slower with the deepening of any bank by reducing the force of the currents, but the upward growths of reef at various points would tend by providing obstructions to accelerate them. The hard bottom, found in the channels, shows that they are still current-swept. The summit of a bank formed by the washing away of land or shoal would be almost flat, and there would not be in any case the much steeper slopes towards the sides, as found in these passages. There is no means of estimating this erosion since the original foundations for the banks commenced to be laid, but it may perhaps be safe to infer from the lesser soundings obtained that about 160 fathoms was the original depth of the plateau.

My conclusion then is that an almost flat plateau at a depth of 160 *fathoms was at one time formed, and that on this the banks severally arose.* So far as sections have been run off atolls in the Indian and Pacific Oceans, there is in all a striking uniformity in slope, a gradual fall—that of the reef platform—to something under 50 fathoms, succeeded by a steeper drop to about 150 fathoms. The agreement in depth with our Maldive plateau suggests that this is the depth to which the oceanic currents have sufficient force to cut down the banks and prevent the fixation of the reef-building organisms, partially directly by their strength and partially indirectly by movement of mud and sand smothering them and preventing their growth[1]. Below this depth I consider that we have the volcanic basis of our banks, as Murray suggested; or, as I think, the remains of an ancient land. In commenting on the cutting down of land Sir A. Geikie postulated that the depth to which the currents would act "is probably nearly coincident with the lower limits of reef-builders." Depths approaching 150 fathoms were not however imagined by anyone, but with increase of knowledge the depth at which it is known that the organisms may dwell has gradually been further and further increased. It has been pointed out by myself and others that reefs are largely formed by calcareous algae (*Lithothamnion*), and that the corals, which cover the reefs, feed mainly by their commensal algae. It follows then that the limit in depth, at which these may exist, is probably dependent on physical questions, chiefly on the power of sunlight to penetrate sea-water, the temperature being assumed to be favourable. There are no absolute experiments on this point, but the results of dredging point to a depth of 150 to 200 fathoms as the effective limit to which nullipores can live.

[1] This may appear at first sight to be inconsistent with other views put forward in this paper. There is however a great difference between the deposition of sand and mud and its smothering action on corals. No sand is normally deposited on the reef-flat, but frequently off islands after a heavy gale or a change of wind large areas of corals on it are found to have been killed by the mud and sand clinging to the tissues and blocking up the mouth parts of the polyps.

The question as to the depth at which reef-corals occur is an important one, and one to which we devoted very particular attention. With open boats and a sailing vessel it was practically impossible to dredge the steep outer slopes of the reef so as to get any sample of the bottom. There was too no other ground in the Maldives with a depth of between 50 and 100 fathoms, so that necessarily our work was confined to depths below the lesser limit (*i.e.* 0 to 50 fathoms). The dredgings between 30 and 50 fathoms outside reefs were very few, but there were a large number in the passages of the atolls and a still larger number in the lagoons. Of the latter only those close to shoals (surface-reefs) would be expected to yield any evidence, since it is only in such positions that a hard rocky bottom, suitable for coral growth, is found. *Heliopora*[1] was obtained off Addu, growing apparently luxuriously at about 40 fathoms, but of genera of true corals at all important on the surface reefs in any region *Madrepora*, *Seriatopora* and *Pocillopora* alone were represented below 30 fathoms. It might possibly have been expected that only branching corals would have been obtained, and that no evidence would hence be forthcoming as to the real depth at which most reef-corals live. Yet in shallower depths colonies of massive species were not infrequently procured, and the characters of the growths of the above-mentioned genera afford the strongest possible deductive proof that reef-corals do not live below about 50 fathoms nor flourish 20 fathoms higher[2]. It was surely remarkable too that such branching corals as *Montipora*, *Porites*, *Pavonia*, *Psammocora*, *Mussa*, *Euphyllia*, etc. besides the hydrocoralline *Millepora*, all common enough on reefs, should not have been represented at all below 30 fathoms. The *Madrepora* secured belonged to finely-branching facies with light coralla, and only a single small piece of a delicate *Seriatopora* was procured. The *Pocillopora* afforded less definite evidence, several pieces of massive facies being brought up, though most colonies were finely branching. Yet compared with the large pieces of coarse *Pocillopora*, apparently of the same species brought from 20 fathoms, its growth is very evidently far from luxuriant at this depth. Dr Bassett-Smith's dredgings on the quite open Tizard and Macclesfield banks, in which he had the use of steam, support the same view, fragments of *Favia* and *Montipora* alone being caught up between 41 and 50 fathoms and only six so-called species from 31 to 40 fathoms[3]. At Funafuti eight dredgings 40 to 140 fathoms on the steep slope of the reef yielded no reef-corals, and with "swabs" 30 to 45 fathoms I only secured about 20 fragments of *Madrepora*, *Pocillopora*, *Stylophora* and *Porites*, with pieces of *Millepora* and *Heliopora*[4]. The characters of the specimens were the same as those subsequently procured in the Maldives, and they are scarcely such as characterise the corals that mainly build up the reefs as we find them in the present day.

It would seem to me then that about 30 fathoms is the extreme limit in depth of the growth of the effective reef-building corals. Our dredgings also brought out the fac that the luxuriance of growth of corals progressively increases as the water becomes shallowe to within a few (3—6) fathoms of the surface. The formation of corallum in corals is, consider, dependent on the excretion of ammonium carbonate, and is directly proportioı to the amount of the metabolism. The latter, so far as the reef-forms are concerned,

[1] *Vide* note on p. 168.

[2] This question will be better brought out and dealt with in the "Report on the Madreporaria," which I am now preparing. I may here mention that, with any genus or species of such corals, the skeleton decreases in density (*i.e.* specific gravity) with increase of depth. Branching forms too have finer and more delicate stems, consi with the limits of variation found in any species. polyps also have a tendency to be further distant one another.

[3] *Ann. Mag. Nat. Hist.*, Nov. 1890.

[4] *Loc. cit.* p. 479.

mainly influenced by the amount of carbonic acid (CO_2) in the water, the circulation of the water, and the quantity and intensity of the light. Temperature is not a factor of vital importance in coral-reef areas. It undoubtedly assists the metabolism, but excess of heat appears to be practically unknown on reefs. I have measured in pools at Minikoi, abounding in corals, temperatures up to 133° F. at low tide; save that the corals tended to expand as soon as the colder tidal waters entered the pool, I could not subsequently see any difference in them to those completely covered with the sea water. So far as cold is concerned I have been unable to trace any death of reef-corals to this source, nor have I found any definite evidence of such recorded. In reference to the carbonic acid the "Challenger" results showed an excess in deep water over shallow, but in any case within 50 fathoms of the surface, well within the wave limits, there could not be much difference in this, the water thoroughly mixing. The real factor is the light, which to reach the commensal algae has to penetrate the tissues of the polyps as well as the water. An intense light is evidently required, and even on the Equator 30 fathoms is almost beyond its limits in the Maldives. On it depends mainly the metabolism, and our dredgings indicate that its action is not great and of little effect below 15 or 20 fathoms. Hence Darwin's conclusion "that in ordinary cases reef-building polypifers do not flourish at greater depths than between 20 and 30 fathoms and rarely at above 15 fathoms"[1] appears to be literally true and amply borne out by our results.

The accounts of nullipores, the depths at which they live, are extremely unsatisfactory, algae being generally much neglected by zoologists, to whom the practical investigation of coral-reef conditions and formation has been, by almost universal consent, relegated. My own investigations have not unfortunately been carried out on such a scale that I can give or indicate any answer to the question of the importance of these forms in building up a reef beyond a depth of 40 to 50 fathoms. To this depth nullipores certainly may and do grow against the open sea in great luxuriance. Their species or facies appear to be the same from the surface down to this depth, and there is no alteration in their texture, no decrease of specific gravity, so far as I could ascertain. At the same time their growth is always extremely slow as compared with corals, and they do not nearly so readily cover a vacant area. Only the smallest growths are found in the oldest cleared out boat-channels through the reefs to the shores of the islands of the different atolls[2], and where beacons or other fixed marks have been placed by the islanders on the reefs, they have not been in any case, that I saw, appreciably covered at their bases by nullipores, although these organisms may clothe the whole basal reef on which they are fixed. Their metabolism also like that of corals must decrease with greater depth, and, although they very certainly are an important contributory agency in building up banks from upwards of 200 fathoms, I must reject them absolutely as in any case capable alone of furnishing a sufficient amount of material to raise the foundations to sufficient depths for the reef-corals to take possession[3].

It remains then to consider what may be the chief contributory agents in building up our banks to the surface from their common plateau 150 or 200 fathoms below. In

[1] *Coral Reefs*, 3rd ed., p. 115 (1889).

[2] Most inhabited islands have one or two boat-passages through the reef around them communicating with the boat-channel inside, where it exists. These passages have by Maldivan law to be cleared out every three years from every scrap of coral or nullipore that may be growing in them, and they are inspected by Government officers to see that this is properly done. The coral, etc. obtained is either taken on shore to be burned into lime, or more often sunk in the lagoon of the atoll outside.

[3] The importance of nullipores is rather in consolidating the corals together. For this purpose they are especially efficient, since their skeletons are scarcely affected by boring organisms.

the first place I am convinced that in such shallow depths in an open ocean the calcareous remains of pelagic or of any free form of life could not to any large degree rest, on account of the tidal and oceanic currents, and hence it is to sedentary forms that we must look for an explanation. The latter has been, I believe, afforded by the discovery of deep coral banks in the Atlantic, of some of which Mr J. Y. Buchanan has given an account[1]. In my paper on Funafuti, Rotuma and Fiji I gave a number of quotations to show the vigorous growth of corals at considerable depths, but I did not then appreciate fully the effects of tide, current and wave actions. The banks, described by Mr Buchanan, appear to have been absolutely formed by these corals and to have been built up by them to comparatively shallow depths. Of the three banks described, the "Coral Patch" was of great interest, having an almost flat summit—least depth 435 fathoms—covered with living *Lophohelia prolifera* and surrounded by precipices from 550 to 850 fathoms. The "Seine bank" had broken coral with apparently some chlorophyllous organism on its summit at 86 fathoms, and the "Dacia bank," 49 fathoms in the centre, was slightly domed in shape with cliffs from 100 to over 300 fathoms. The deduction that the precipitous portions of these banks are formed by the dead coralla, the living polyps building on the dead "bones" of their parents, appears to me a perfectly legitimate and indeed the only possible one. The largest bank, the Dacia, is small as compared with the Maldive banks, being only 8½ miles in diameter. Yet in the same paper indications of similar larger banks in the Atlantic are given, and it appears to me quite reasonable to suppose that the separate Maldive banks were built up somewhat in the same way. The Maldive plateau being of long, narrow shape, of considerable size, at no great distance from continental land, and in the track of oceanic currents, would be affected differently to smaller banks. On the latter the conditions of food over the whole surface would be nearly the same, the organisms raining down on them fairly evenly from the water above. Such banks hence would be covered all over with corals, causing them to grow up nearly flat or slightly domed. On account of the direction of the Maldive plateau the currents would necessarily set right across it, and its sides accordingly, being best provided with food, should naturally be expected to grow up the faster. As they got higher and presented more obstructions, channels might well be broken through and further cleared out, giving rise to those found at the present day between the different atolls[2].

Nullipores, as the shoals approached the surface, would naturally become of increasing importance, but there is some evidence to show that the class of corals, that built up the banks, cannot live in shallow depths, though the precise cause of this is not clear. It may partially be temperature, though pressure is a probable contributory cause as well, since their distribution in depth is limited in temperate regions as well. The Seine bank was covered with broken and dead corals, and the Dacia was probably also, its surface evidently being very rough. Perhaps 50 fathoms or so is the limit of the upward growth of the deep corals. Possibly they build up until they are finally extinguished by the reef-corals. Whatever may be the case is immaterial, as there is a third class of corals that can live either on the reefs or near the surface, where there is little competition, but flourishes best at 30 to 50 fathoms. This class, as are the deeper corals, is not dependent on its algae for nutriment,

[1] "On Oceanic Shoals discovered in s.s. Dacia in October 1883." *Proc. R. S. Edin.*, vol. XIII. p. 428, 1885.

[2] As soon as the sides of the plateau commenced to grow up, mud would necessarily be swept over the central part of the plateau and would effectually kill any corals or other sedentary organisms. On account of the current being accentuated by the upgrowth of the sides, the channels would probably form at an early stage. The eddies, formed by the currents through the channels meeting in the centre of the plateau, might account for the shape of the banks.

and perhaps deserves a more precise notice here. Of first importance so far as massiveness is concerned may be placed *Heliopora*, which I obtained off Funafuti from the same depths. In all four dredgings outside Addu atoll it was obtained, and from the quantity procured seemed extremely abundant; it too was not bored into by organisms in any way. The genus is also found living in the lagoons of atolls in the Maldives, but I never saw it living on the reef-flat or outer slope to 15 fathoms. In the lagoons the colonies are closely packed with lamellae and stunted. Of true corals in this class (Madreporaria) many large masses of *Goniopora* and *Alveopora* of several species were brought up from the lagoons, and solitary corals were in places extraordinarily numerous. *Cycloseris* was found on nearly every bank, and in one of the north passages into Suvadiva atoll with 38 fathoms of water were trawled great masses of rubble, formed almost entirely of its dead coralla. The most important genus however was *Dendrophyllia*[1], of which a very dark green velvety species (*D. ramea*, sp. ?) formed great dense groves in nearly every passage into the interiors of the banks. We never obtained it below 45 fathoms, nor above 15, but between these depths, if the bottom was at all rocky, the dredges seldom came up without some of its branches. Many other corals could doubtless be added to this list, but the above seemed the most important forms in the Maldives, which might be expected to raise the reefs in their later stages, and afford foundations for the more vigorously-growing reef-species. In addition there is the increasing importance of the nullipores on increase of depth, and *Polytrema* and other Foraminifera also, with Mollusca and other forms doubtless assist. Perhaps indeed all these are unnecessary, but their enumeration serves to point out their possible economic position in the formation of the reef.

The next stage is dependent on the arrival of the larvae of the reef-building corals. Some fix themselves, and their resulting colonies soon commence to struggle with the possessors of the ground for supremacy. Their arrival is but slow, and at first they are probably spread out over the surface of the whole reef. As the shoal grows up oceanic and tidal currents over it become more definite. Its edges are more bathed than its central part and more oxygen, carbonic acid and food are carried to them. As a result the rims in particular soon send patches of reef up to the surface, to give rise finally to the perfect atoll through a series of changes, such as are sketched in my account of North Mahlos.

The depth, to which the shoal would be raised before the reef-corals obtained sway, would naturally to some degree vary in different regions with their diverse conditions, and on this in the first place would depend the depth of the subsequent lagoon. It is not until the rim becomes moderately perfect that the latter begins to be hollowed out by solution, and until then its depth in the centre depends on that of the original shoal. In this case Tiladumati-Miladumadulu and Mahlos might be expected to show these depths, *i.e.* 25 and 26 fathoms, while the atolls to the south demonstrate the increase of depth as the rim perfects itself. In this connection stress must only be laid on banks of considerable size, small ones having from the first more perfect reefs. The wave and current actions must be much less obstructed by small reefs, and hence there would be some considerable circulation of water over every part of them. They would then have been more covered over with reef-corals, and would accordingly, when they grew up, have shallower lagoons. The very smallest would have a solid, flat surface-reef with no lagoon at all. The larger atolls of this class probably include Goifurfehendu 23 fathoms, Rasdu 21 fathoms, Wattaru

[1] *Vide* note on p. 168.

18 fathoms, Makunudu 19 fathoms, and Ihavandifolu 28 fathoms, besides some of those in the Laccadives. Toddu, Karidu, and Fua-Mulaku, being smaller, have not yet attained by secondary means, *i.e.* growth outwards and solution of central parts, the atoll condition, and their reefs being still crowned with land will have to be reduced to the bare reef before they can do so.

This depth, about 26 fathoms, found in Tiladumati-Miladumadulu and Mahlos is the same also as occurs on many submerged banks. In the first place attention may be called to those in the Laccadives, as they have not yet begun to assume an atoll shape. Of these one is small and has only 6 fathoms of water, but the other three are much larger and have 23, 26 and 28 fathoms. Indirectly these banks too serve to give additional proof of the above theories. Being domed they cannot be submerged atolls. Considerable irregularity in depth strongly opposes the idea that they are still being cut down by the sea. Further they have apparently precipitous walls. If the encircling reefs of atolls do ever actually grow up directly from 40 to 50 fathoms, taking the depths of the lagoons of some, it is remarkable that these banks as yet show no signs of any such reefs. Turning to the shoals of the Pacific I may refer to those recently mentioned by Admiral Sir W. L. Wharton to the north of Fiji, five in number, with depths of 24 to 26 fathoms in their centres. The second largest of these, the Alexa bank, 18 by 9 miles, has a perfect rim 13 to 18 fathoms in depth. Speaker's and Pitt banks in the Chagos are also nearly comparable in size and have 24 and 22 fathoms. Many other similar shoals might be cited, but reference may be made rather to those which markedly differ. First Saya de Malha has a sounding of 65 on the centre but only 22 fathoms on the rim; yet the merest glance at the chart on p. 14 serves to show that it is in its foundations comparable rather to the great Maldive plateau than to its several banks. Great Chagos, Tizard and Macclesfield all have over 45 fathoms. The first is of great size (see p. 17), and all three have the rim though largely submerged far more perfect than that, for instance, of Tiladumati-Miladumadulu. The larger the bank the more tendency there is for the rim to grow up from a greater depth, as more food would reach the sides before the centre. However, as already remarked, the formation of each reef must be considered by itself in view of the physical conditions of its region. These may be expected to profoundly modify it, and probably are largely responsible for the variations that occur. In the above I have only tried to sketch the conditions which have been affecting the formation of the reefs in the Maldives. I would not necessarily apply them to all reefs, though I believe that in their main principles they will be found to be true also of the greater number in the Pacific and Indian Oceans.

I have already indicated under Mahlos the changes that take place to form an atoll, but a further reference is necessary to the enclosing or rim reefs. These may in the smaller banks almost grow up as such in the perfect state, more or less completely surrounding the lagoon. The relative length of the reef roughly varies inversely as the size of the bank, and the amount of water which must pass over it directly. Further, the greater part of the current, oceanic or tidal, may be diverted on either side of a small bank, whereas a relatively much greater amount of water, conditions of depth, etc. being the same, must pass over the encircling reef of a larger bank. Such being obviously the case it is apparent that the outfalls for the water may be relatively very much less numerous and smaller from small than large banks. Again, the amount of current will increase with the contiguity

of other banks, and also if there is—instead of deep sea—shallow water, a ridge in fact on either side. The consideration of the current factor is, I believe, a most important one. It acts on coral growth in two ways, advantageously by constantly bringing fresh water and disadvantageously by sweeping sediment over the corals, by preventing fixation of the larvae, and, when strong, by stunting and even breaking the corals. On a bank at 25 to 30 fathoms patches all over the surface would commence to grow up, wherever the conditions might happen to be especially advantageous. A fairly definite rim might early be expected to show itself, but together with its growth there would be an increase of current over the bank. If the bank be small or isolated there might not be a sufficient increase to affect the growth of the rim as a whole, though some parts would possibly from the first be lower and, serving as outfalls for the water, form the passages. In this way atolls such as Addu and Goifurfehendu and others have probably been formed.

On the other hand, in atolls of the next size some part of the rim might be more perfect from the commencement, and in the central banks of the Maldives it would naturally be that on the east side of the east line of reefs and on the west of the west line, these sides being more exposed to the sea and hence to more favourable conditions. This is at once illustrated in the more perfect reefs of these two sides in Felidu, Mulaku, North and South Nilandu and Fadifolu atolls. Lastly over the largest banks of the central plateau the currents, both oceanic and tidal, must be from their position and size much stronger, and probably from the first in Mahlos and Tiladumati-Miladumadulu the corals could only build up patches of reef on the rim. The condition would remain open and shoals would grow up anywhere on the centre of the bank. Until the wall of the bank became fairly perfect each patch would behave as an isolated reef in the ocean, and by spreading out on all sides and becoming hollowed in the centre form an atoll. The rate at which this might occur would, as compared with an isolated reef in the ocean, be enormously increased owing to the shallow depth of the foundations on which the corals would spread out to almost any extent.

Of other atolls in the Maldives Kolumadulu and Haddumati are exposed both east and west to the full action of the sea, and are less enclosed than others by their neighbours. They only differ from Suvadiva in their smaller size, but the latter is still less contiguous to its fellows. The encircling reefs of these banks are fairly perfect, though they are broken by numerous passages into their lagoons. A study of their lines of circumscribing reefs shows that the conditions are not so simple as at first sight might appear, since they have a line of shallow pools along their centres. Either the rim grew up double—the conditions inside such large banks being supposed to be the same as outside—or the reefs were formed by the fusion of a series of faro. The first condition is conceivable and partially accounts for the outgrowth of the ring-reefs of Mahlos, but such growth only continues while the passages into the bank are numerous. Between these pools the encircling reef narrows somewhat, and its close examination shows that it was rather formed by the fusion together of an enormous number of little patches. For this fusion to have taken place on some banks, while the patches are still separate in so many others, the rim as a whole must have grown considerably and the passages been shallow, but then there is the elevation of the group, which with shallow channels may have been of great assistance. It is not necessary, however, that each passage should have had at least its present depth of water at all times; many are being filled up by coral growth, and it is more than probable

that others, through which tide and current particularly sweep, may have been and are being cleared out and deepened.

It remains then to consider the reef-platform, which slopes gradually down to the commencement of the steep at about 40 fathoms. Why does not the whole grow up as a wall to the surface? To this question it is hard to give any answer on account of our ignorance of this slope, of what even its surface is like and what covers it. We are not in a position to theorise about it, but I should not suppose that the greater part of it came into existence contemporaneously with that of the foundation-bank. It is, so far as I am aware, a feature of all surface oceanic reefs in both the Pacific and Indian Oceans, and varies little in depth and breadth. There is no reason to suppose that the original shoals had any such tailing off. In the Maldives I did not particularly investigate this platform, but my soundings were sufficient to show that it is fairly regular on all sides of all banks save towards the interior of our plateau. In fact it was regular against all parts of the banks that were fairly freely exposed to the ocean. Off the west of Fadifolu I endeavoured for a short distance to place in both the 50 and 100 fathom lines. The two lines were generally separated from one another by no more than the length of my whale-boat, the slope from one to the other being certainly over 75°. I hence restricted myself to observing the 50 fathom line. It varied inside the banks from 50 to 300 yards from the edge of the reef-flat, in the majority of places being less than 100 yards. The steep generally commenced at about 20 fathoms, hence much below the depth usual outside atolls. This difference indicates that there is some action, much stronger outside the atolls, that forms this platform. This I conceive to be the current action, largely set up by the waves, and it is to it that I would look for an explanation of the shallow slope. The oncoming waves carry a large quantity of water against the reef, the most of which is thrown back in a deeper current, sweeping down the slope (see p. 24). The strength of this, weather conditions being constant, will depend on the exposure of the reef to the sea and on the height to which it rises in the water. For our purposes the reef may be assumed to reach the surface as in the Maldive banks. There is left then the question of exposure, which would naturally be much less on the inner sides of the banks. The outgoing currents would be less strong on the inner sides, and material would be carried out to a lesser depth than on the seaward sides. The quantity of lime thrown over the steep on the outer side would be very much greater than on the inner side. The depth at the edge of the reef-platform I would regard as the depth to which the current can sweep out the heavier masses of lime from the reef above. A considerable part of the reef to seaward might then have been formed of masses, piled up by this means. Against the deep channels between the several banks the strong currents would preserve for a long time the original, almost perpendicular slope, and from the lesser growth and protected situation within the bank the platform would be of less definite form and the original slope would be preserved. The Laccadive banks also support this view, in that the reef-platform on the west side of the reefs is of the regular slope and breadth, while on the east, which is protected by the Indian Peninsula, it is usually almost non-existent or else very narrow (Plate VIII.).

The matter in this chapter is, I fear, so extremely complicated on account of the varied conditions on the banks that it does not lend itself to the formulation of conclusions *in a brief set of words. I may, however, present some of my views as to the formation of the*

group in the pictorial method of expression by means of the accompanying diagrammatical section of the outside of a bank (fig. 33) as I suppose it to have been formed:—

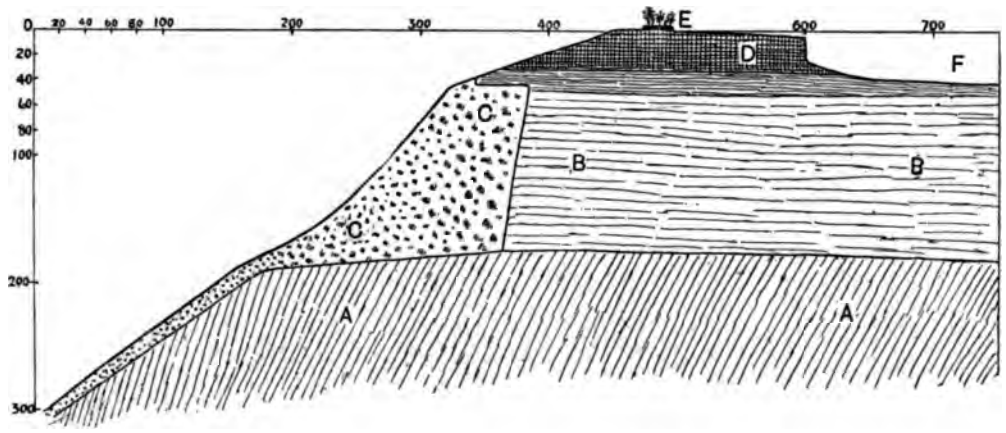

FIG. 33. *Scale in fathoms.*

A. *Basis of primitive rock, cut down by the action of the currents to this depth. This is deeper in the central basin of the plateau and in the channels between the several banks on account of additional erosive action since the latter commenced to grow up.*

B. *Upgrowth of a shoal by means of deep sea corals assisted somewhat by nullipores and other organisms. The more densely shaded area at the top shows the line in which the deep corals cease to grow and the reef forms commence; the reef, however, is in this part mainly built up by the intermediate depth corals and other organisms.*

C. *Outward extension of the reef by means of detritus, swept off the reef above by the currents.*

D. *Surface reef formed by true corals, nullipores, etc.*

E. *Land, formed by elevation or a change of level of the ocean.*

F. *Lagoon, formed partially by the more rapid growth of the organisms on the edge of the bank, building up an encircling reef, and partially by the subsequent solution of the central parts.*

(*To be continued.*)

ON THE PIGMENTS OF CERTAIN CORALS,
WITH A NOTE ON THE PIGMENT OF AN ASTEROID.

By C. A. MacMunn, M.A., M.D., etc.

(With Fig. 34.)

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1. Coenopsammia willeyi (from Hulule)[1]. [Fig. 34.]

Alcohol extract of dried coral. Fig. 34. 1.

When coarsely powdered and extracted with absolute alcohol and let stand for 24 hours, or longer, a greenish-yellow solution was obtained, which had a red fluorescence, and showed the spectrum of a *chlorophylloid* substance in solution, but no lipochrome bands. The bands in this alcohol solution read:—1st, λ 674 to λ 635, 2nd a faint band, λ 619 to λ 595. Traces of two other bands nearer the violet were also seen—in the green. Ether extracts the same colouring matter from the dried coral.

[1] [For description of the species see Willey's *Zoological Results*, Part IV. pp. 357 et seq. (1900). I have examined by sections the polyps of both species of *Coenopsammia* and the species of *Dendrophyllia*, whose pigments are reported upon in this paper. They have no commensal algae, such as are found in most reef corals, and I have been unable to find any algal matter in their coelentera. The specimens sent to Dr MacMunn consisted of the dried coralla with the animal part still remaining on the same. In some cases the corallum had been stained slightly by the diffusion of the pigment, which is situated in the external ectoderm alone.

Coenopsammia willeyi grows for the most part on the under-surfaces of the masses of the boulder zone, wherever there is a free circulation of water and no sand. Only one colony was found in Minikoi, but the species is fairly numerous throughout the Maldives in suitable positions. The colour when alive is a light, uniform, rather iridescent brick-red. Ed.]

On evaporating the alcohol solution to dryness on the water-bath, a residue partly brown and partly green was obtained, soluble in absolute alcohol, forming a dull green solution with a red fluorescence. In this solution the four bands referred to above were visible, but no lipochrome bands. The residue is also soluble in ether, in chloroform and in carbon disulphide, each solution showing the same chlorophylloid spectrum; the position of the bands varying according to the nature of the solvent.

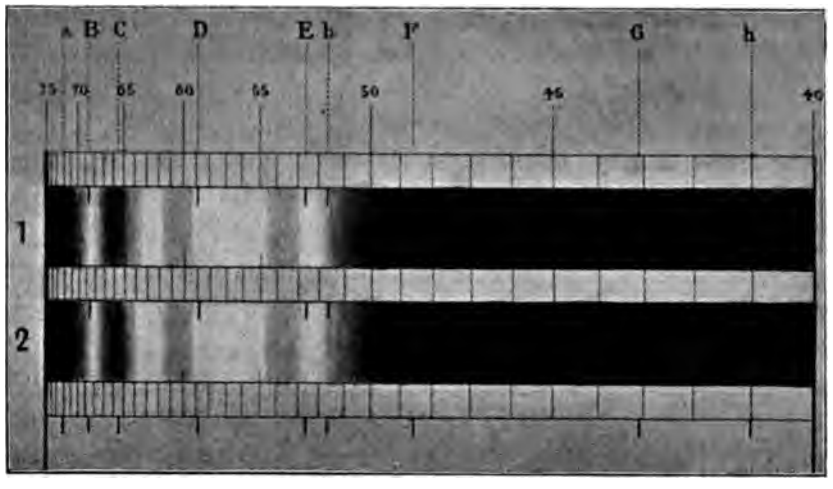

FIG. 34. Spectra of the pigments of *Coenopsammia willeyi*.
1. Alcohol extract of the dried coral. 2. Alcohol extract of the decalcified coral.

Pigments of the decalcified coral. Fig. 34. 2.

The coral was now decalcified by means of hydrochloric acid, at first of the strength of 1 to 4; afterwards the strong acid was added, from time to time, as required. When the lime-salts had been dissolved the soft brownish residue was washed with water until free from acid, on the filter paper. The wash water had a yellowish colour but showed no bands. The brownish acid-free pigmented substance itself gave no bands and was therefore free from polyperythrin.

The brown decalcified substance was then treated with absolute alcohol which soon assumed a deep yellow colour and had a red fluorescence, and showed the same chlorophylloid spectrum as the alcohol solution of the dried (undecalcified) coral itself. The solution showed four bands of which three read:—1st, λ 672 to λ 639, including shadings, dark from λ 670 to λ 650·5, 2nd about λ 616 to λ 595, and 3rd about λ 545 to λ 531. *So that here the chlorophylloid pigment occurs united with lime-salts*, and no lipochrome could be detected.

Solution of pigment in NaHO.

Those portions of pigment of the decalcified corallum which were insoluble in alcohol were treated with caustic soda (weak). The solution on filtering had a reddish brown colour, but showed no bands, and absorbed the violet end of the spectrum. The addition of hydrochloric acid to this caustic soda solution causes partial precipitation of this pigment, and after filtering a brownish pigment is obtained. It is insoluble in ether, chloroform, alcohol, water or water acidulated with hydrochloric acid, but soluble in weak aqueous solution of caustic soda.

This pigment is evidently the main cause of the colour of the coral.

2. Coenopsammia nigrescens (from Hulule)[1].

Alcohol extract of dried coral.

An alcohol solution of the coarsely powdered coral was of a greenish-yellow tinge. In a layer of 10 centimetres deep a band could be seen in the red, due to a trace of a chlorophylloid pigment, and reading from λ 670 to λ 648. On evaporation on the water-bath a residue partly greenish-yellow and partly brownish was obtained, but this residue is more yellow (or reddish-yellow) than in the case of *C. willeyi*, and it is not wholly soluble in ether. The ethereal solution was reddish-yellow and left on evaporation a yellow residue soluble in the same solvents as in the case of *C. willeyi*.

Pigments of the decalcified coral.

The coarsely powdered coral was then after the alcohol extraction treated with dilute hydrochloric acid 1 in 4, then with the strong acid. On filtering off the soft decalcified coloured parts from the acid, the latter was found to have a reddish-yellow colour; this solution absorbed the violet end of the spectrum but gave no bands.

The soft pigmented parts of the decalcified coral were then washed free from acid and treated with absolute alcohol: but only a little pigment went into this.

This filtered alcohol extract had a greenish-yellow colour and did not show a noticeable red fluorescence, and did not give a band in red. It however strongly absorbed the violet end of the spectrum. On evaporating this solution an orange-coloured residue was left: partially soluble in ether and in chloroform, the solution showing no bands. That part of the pigment insoluble in these solvents was yellow. Here again the absence of a lipochrome was noticeable.

Solution of pigment in NaHO.

The decalcified coral after extraction with alcohol was now treated with caustic soda and water and filtered. The filtrate was of a reddish-brown colour and absorbed the violet end of the spectrum but showed no bands, nor were any visible on adding sulphide of ammonium.

Hydrochloric acid did not precipitate out this pigment to any marked extent even when added to excess. The little pigment precipitated out and filtered off was of a brown colour, insoluble in ether, chloroform, or absolute alcohol and soluble in weak acid and alkaline aqueous solutions.

Here again no polyperythrin was present.

3. Dendrophyllia ramea[2].

Alcohol extract of dried coral.

The dried coral was extracted with alcohol and yielded a yellow solution. This showed no absorption bands, nor had it a red fluorescence. It absorbed the violet end of the spectrum; in a deep layer at λ 480 completely. On evaporation a brownish, and in thinner parts a yellowish, residue was left. This was soluble in ether but

[1] [*Vide* Milne Edwards and Haime, *Cor.* III. p. 128. The species was only found in the Maldives. It occurs in the same position as *C. willeyi*, but is much less common. The colour, when alive, is a uniform, dull, cloth-black. Ed.]

[2] [All the specimens of *Dendrophyllia* appear to me to belong or closely approximate to this species (see Milne Edwards and Haime, *Cor.* III. p. 115). The species is very common in the passages of the atolls and banks in the Maldives from 15 to 40 fathoms. It also is found within the banks, wherever there is a sufficient current to keep the bottom fairly clear of mud and sand. The colour, when alive, is a somewhat iridescent black with very dark olive-green in the peristome, lighter immediately around the stomodoeum. Ed.]

not quite as soluble in alcohol; soluble in chloroform, forming a reddish-orange solution, and in carbon disulphide. In none of these solutions were any bands detectable. This residue (*quite free from any traces of alcohol*) became *redder* with strong nitric acid and with sulphuric acid, and *a marked red* with iodine in iodide of potassium solution. Hence this pigment is not a lipochrome.

Pigments of decalcified coral.

The coral was decalcified by means of hydrochloric acid as before. The acid however —differing in this respect from the above corals—took up some pigment, the solution after filtering being of a brown or reddish-brown tint. In this solution no absorption-bands could be seen: the violet end of the spectrum only being absorbed. If caustic soda be added in excess to this solution the pigment may be precipitated out.

The colouring matter seems mainly to occur in the superficial layer of the coral: as taught by the action of hydrochloric acid. The decalcified masses of pigmentary substance when examined in a compressorium showed no bands; hence no polyperythrin was present: they are black in thick, and brownish in thin layers.

The alcohol extract of decalcified coral.

By extracting the pigmented masses with alcohol a solution of a pale greenish colour was obtained which absorbed the violet end of the spectrum abruptly: no bands could be seen. On evaporation this left a yellow residue, which seemed to become brown by prolonged heating on the water-bath. Ether only took up part of this residue, leaving yellow flocks of pigment undissolved. This ether solution was yellow and showed a faint band at *D*; so that this pigment had changed by heating. This band read (about) from $\lambda 580$ to $\lambda 615$. On evaporating the ether a yellow and in part greenish residue was left: this was only partially soluble in chloroform, and this on evaporation left a residue partly yellow and partly dark brown. This residue was now only partially soluble in alcohol: so that the heating as stated had decomposed the pigment.

The residue left from the evaporation of this last alcohol solution became distinctly *red* with nitric acid, gave no distinct coloration with sulphuric acid, and gave a fine *brilliant red* with iodine in potassic iodide solution. This last reaction was very remarkable, and was yielded by both the brown and the yellow portions of the residue.

Solution of pigment of decalcified coral in NaHO.

Caustic soda in aqueous solution extracted—after the decalcified coral had been already extracted with alcohol—the dark pigment in considerable amount. The solution being almost black, but by transmitted incandescent (electric) light it appeared reddish or brown-reddish. In a deep layer this let through the red rays, in less deep the red and green, and in less deep still the violet end of the spectrum only was absorbed. No band was seen, nor on the addition of ammonium sulphide.

By adding hydrochloric acid to this solution to acidity a precipitate fell. This was filtered off and washed, and was of a brown colour: insoluble in ether, *soluble in alcohol*, insoluble in water, and soluble in aqueous solutions of caustic soda.

I stated above that hydrochloric acid extracted some dark pigment also from this coral which was partially precipitated by adding caustic soda to alkalinity. Now this latter pigment differs from that just described in some respects, as it is insoluble in alcohol, and *insoluble* in aqueous solution of caustic soda. Hence there appear to be two dark pigments colouring this coral; and no lipochromes are present in it.

4. Heliopora coerulea[1].

Alcohol extract of dried coral.

On extracting the coarsely-powdered, dry coral with alcohol a solution of a bluish-green colour was obtained which had a red fluorescence. This showed a band in the red from λ 670 to λ 644.

The solution was evaporated at the temperature of the air, and left a blue-green residue. Redissolved in absolute alcohol a blue-green solution was obtained, which had a red fluorescence and showed four absorption bands which read:—1st, from λ 674 to λ 635, including shadings, 2nd a shadow from λ 616 to λ 592, 3rd from λ 577 to λ 560? and 4th from λ 545 to λ 531. This spectrum denotes the presence of a chlorophylloid substance, but it was not accompanied by a lipochrome.

The pigment of the decalcified coral.

The powdered coral, already extracted with alcohol, was decalcified as before. The acid solution appeared blue but this was found to be due to particles in suspension —as it disappeared on filtering. On extracting the decalcified blue parts of the coral with rectified spirit a fine blue solution was obtained, like ammoniated sulphate of copper solution. This solution showed no absorption band, but transmitted the blue, green, and yellow of the spectrum and cut off a portion of the red end. Caustic soda discharged a part of the blue colour but did not destroy it.

A deep layer of neutral spirit solution of *helioporin*—as we may call it—more or less absorbed the red end of the spectrum up to and beyond the *D* line.

On evaporating such an alcoholic solution on the water-bath a blue residue was left. This was insoluble in ether, in chloroform, and in water, soluble in alcohol, but not as freely as before it was evaporated by means of heat. A further confirmation of the change undergone by the pigment in solution by heating was shown by the appearance of a band in red and one in the yellow at the *D* line. These bands reminded one of the chlorophylloid spectrum of the alcohol extract of the dried, undecalcified coral, and probably point to the connection between helioporin and this chlorophylloid pigment. Such a solution changed further on standing exposed to the air to a purplish tint, but still showed the two absorption bands referred to above.

Moseley, who first described this blue pigment of *Heliopora*[2], says that nitric acid destroys the blue colour of *Heliopora*. I found that nitric acid added to the alcohol solution made the colour more lavender, but did not remove it. Hydrochloric acid made the colour bluer. Caustic alkalies change the colour to a dirty green, as Moseley described. Here again no lipochrome bands could be detected.

This blue pigment decreases as the depth increases in which the coral lives; thus in the specimens sent me I found that the greatest amount of helioporin was present in specimens from the reef, which were coloured dark blue. Those dredged from a depth of 25 fathoms

[1] [In this case the pigment is situated in the corallum which is completely external to the living tissues. Most of the specimens, submitted to Dr MacMunn, had been cleaned by exposure for a long period of time to the sun and rain. The genus is found sparingly on the sand flats within the outer reefs of the atolls of the Maldives, and was obtained also in various dredgings between 25 and 45 fathoms. On the outer slope of Addu Atoll it seemed the most important reef builder at the depth of 40 fathoms. Ed.]

[2] *Quart. Jl. Micro. Sc.* vol. xvii. N. S. p. 2.

were much darker than those dredged from a depth of 40 fathoms, and what is of great importance, the side of the corallum next the surface, and therefore more exposed to sunlight, was a deeper blue than the opposite side.

5. Remarks on the Coral Pigments.

Of the above pigments some belong to those which may be called chlorophylloid, whether they are intrinsic to the coral, whether they are digestive products, or whether they are due to the presence of symbiotic algae. The other pigments found being probably "lipochromoids" and "melanoids." These latter were first described by the late Professor Krukenberg[1]. The occurrence of the chlorophylloid pigments is of great interest. Prof. Sidney Hickson has expressed the opinion that corals probably contain chlorophyll or an analogous substance[2]. I may refer to the paper of the late Professor Krukenberg again in this connection, "Die Farben der lebenden Korallen des Rothen Meeres," in which he describes a *chlorophylloid* pigment in various *fresh* corals. In stating that this pigment is a "hepatochrome" (or an enterochlorophyll) he is however not correct, as can easily be proved. The greater abundance of helioporin in the surface exposed to sunlight, and its diminution, or even absence, on the lower surface of the corallum, and further its apparent relationship to a chlorophylloid substance, is of great interest.

Doubtless these pigments are of physiological importance to the corals, as Prof. Hickson infers. And the dark pigments referred to above when in solution have the property of arresting the ultra-violet and violet rays of light: in this way they probably act as a screen, protecting the delicate organisms from the irritating effects of the rays of short wave-length.

The pigments, then, of the above corals are either chlorophylloid, or of a closely connected kind of pigment, which latter absorbs the violet end of the spectrum, and seems generally changeable into the next kind, by the agency of heat, etc., namely, into the dark pigment which gives the coral its dark colour in the fresh condition: e.g. brick-red, as in *C. willeyi*, or cloth-black, as in *C. nigrescens*, or velvet-black, as in *Dendrophyllia ramea*. This dark pigment is, as said above, extractable from the decalcified corallum by means of caustic alkali in aqueous solution. I would call attention more especially to the absence of lipochromes, even in the case of the corals possessing a chlorophylloid pigment, and to the presence of the peculiar pigments in some corals, which while being soluble in fat solvents like the lipochromes, yet instead of giving the lipochrome reaction, give a *red* reaction with nitric acid, sulphuric acid and iodine in potassium iodide solution.

6. Integumental Pigment of a Red Asteroid (*Ophidiaster cylindricus*[3]).

The specimens were preserved in pure 70 per cent. spirit and were more or less mottled of a bright red colour. As the spirit was colourless it was evident that the specimens did not owe this colour to a red lipochrome so common among starfishes found in British seas. (MacMunn.)

[1] *Centralbl. f. d. med. Wissenschaften*, 1883, No. 44.

[2] See *A Naturalist in North Celebes*, pp. 149—151.

[3] [I am indebted to Prof. Jeffrey Bell of the British Museum for this identification. Ed.]

On treatment with rectified spirit acidulated with sulphuric acid, only some yellow pigment went into solution; effervescence took place and it was evident that red pigment occurred in combination with lime. It was also evident that no haematoporphyrin was present[1].

On acting on the integument with hydrochloric acid and water a fine red solution was obtained which showed under the microspectroscope a broad band or shading in the green: extending from about $\lambda 566$ to $\lambda 495$. In deep layers the violet end of the spectrum was strongly obscured. Caustic soda was then added drop by drop until the solution became alkaline, the precipitate—consisting of sodium chloride—was pale pink, and on filtering, the filtrate was almost colourless. Alkalies do not therefore destroy the red colour. This pigment was found to be insoluble in ether and in chloroform.

[1] See the papers by MacMunn in *Journal of Physiology*, vol. VII. No. 3, and vol. VIII. No. 6.

MARINE CRUSTACEANS.

I. ON VARIETIES. II. PORTUNIDAE.

By L. A. Borradaile, M.A., *Lecturer in Natural Sciences of Selwyn College, Cambridge.*

(With Text-figures 35—38.)

INTRODUCTION.

The collection of Crustaceans from the Island of Minikoi[1] and the Maldive Group has been divided, for purposes of description and comment, into two halves of widely different biological interest. Of these the first, containing the land forms, has been reported upon in Part I. of this publication. The second, containing the marine forms, is too bulky to be described in a single article, and has accordingly been divided into a series of sections which will be dealt with by instalments, of which these pages form the first. Most of the sections will be undertaken by the writer of this introduction, but the collection of prawns of the family Alpheidae is in the hands of Professor Coutière, of Paris.

In reporting on such a collection as this, various questions of a general nature arise, such as that of the crustacean fauna of the several zones of depth, which are best left over for consideration till the whole of the material has been examined. Meanwhile, however, there is one such question which seems to demand attention at an earlier stage. In former papers[2] I have often had occasion to describe and classify groups of individuals to which

[1] By one of the fatalities that wait upon all expeditions, a great part of the Crustaceans from Minikoi were destroyed on the way to England. Fortunately the accident is mitigated by the fact that it is often possible to recognise in the Maldive collection forms seen at Minikoi. It will be necessary to allude to this in the course of the following sections, but the warning must now be given that the absence of mention of Minikoi as a locality for any species is not to be taken to mean that it is not to be found there.

[A large spirit-tank was apparently tapped on the way home and the greater part of the fluid withdrawn. It contained in numbered packages Mr Borradaile's and my collections of Crustacea from Minikoi, which were almost completely rotted. The loss is greatly to be regretted, as the habitat, mode of life, etc., in short the natural history of the specimens in each bag was carefully noted and there is now no means of ascertaining to what species Mr Borradaile's notes apply. Ed.]

[2] "On some Crustaceans from the South Pacific," Pts. I. II. IV. and V., *P. Z. S.* 1898, pp. 32 and 457; and 1900, pp. 568 and 795; and "On the Stomatopoda and Macrura brought by Dr Willey from the South Seas," Willey's *Zool. Results*, Pt. IV., Cambridge, 1900.

I gave the recognised name of "variety," without attempting to define what that name meant. In many of the sections of this series similar groups of individuals occur, and it seems well to indicate at the outset what value is put upon them, both for the immediate purpose of the better description of the collection in hand, and in the hope of helping other workers in the same field. From these considerations there arise certain others regarding the ultimate nature and fate of varieties, and I shall endeavour to show in what direction my own speculation on this subject has led me. I am well aware that an experience, not of four years, but of forty would barely qualify an investigator to speak with sufficient authority for his words to carry conviction on such intricate and disputed points. But it seems well to indicate in general terms what are the problems involved from the point of view of the systematist.

The first article in the series will therefore be devoted to some remarks on the subject of varieties in the Decapoda. The second and following ones will contain the systematic lists, and the whole will be brought to an end by a discussion of such general questions as may be suggested by the material. Wherever possible the only references will be to Major Alcock's excellent lists of the Indian crabs, which contain full bibliographies and accurate descriptions of the species. These papers appeared in the *Journal of the Royal Asiatic Society of Bengal:* Part 1 (Oxyrhyncha) in Vol. LXIV. ii. p. 157 (1895): Part 2 (Oxystomata) in Vol. LXV. ii. p. 296 (1896): Part 3 (Xanthidae) in Vol. LXVII. ii. p. 67 (1898): Part 4 (Portunidae, etc.) in Vol. LXVIII. ii. p. 1 (1899): Part 5 (Dromiaceae) in Vol. LXVIII. ii. p. 123 (1899): Part 6 (Catometopa) in Vol. LXIX. ii. p. 279 (1900). A reference to this work is to be understood by the mention of Major Alcock's name and the numbers of the part and page of the article referred to. In other cases references will be limited, as far as may be, to indicating a single paper in which a reliable synonymy may be found.

The classification adopted is that of Ortmann in Bronn's "Thierreich," with certain modifications of my own, proposed in a paper in the *Proceedings of the Zoological Society* for 1900 (pp. 568—596).

The several sections will not deal with groups of equal taxonomic value, nor will these necessarily be considered in systematic order. Section II, included in the present instalment, is devoted to the Swimming Crabs (Portunidae).

In conclusion I may be allowed to repeat the acknowledgements I have already made to the Managers of the Balfour Memorial Fund and the Drapers' Company of London for their aid. Nor can I sufficiently express my obligation to Mr Stanley Gardiner for the assistance his great knowledge of tropical marine biology has been to me, confirming, as it has, my own less experienced observations, and for much kind advice on other points.

I. VARIETIES[1] IN THE DECAPOD CRUSTACEANS.

1. *The Nature of Varieties.*

In sorting out a collection of Crabs or Prawns, it is probably the habit of many systematists to separate groups of specimens which seem to belong to single species, and afterwards to examine each of these groups with more care. Now in many cases such a group will prove to be homogeneous, that is, to consist of individuals, differing from one another, it is true, in a greater or less degree, but not separable by their differences into sub-groups. Such a group will be regarded as a *species*. But in other cases careful examination of the specimens will reveal amongst them well-marked differences by which they can be separated into two or more sub-groups. Further, these sub-groups may either be entirely independent of one another, in which case we are dealing with two species confounded at first sorting, or they may be connected by specimens[2] intermediate between them with regard to the features by which they are separated, and not otherwise sharply marked off from them. Such sub-groups are called *varieties*. It must, however, be borne in mind that the intermediate specimens between varieties are much less numerous than those which exhibit the peculiarities of the varieties in a typical development. Otherwise it is only possible to say that the species exhibits considerable range of variation, but that definite varieties are not established. In my own experience, however, wide variability without the formation of definite varieties is rare among Decapods.

The difference, then, between species and varieties as recognised in systematic Carcinology is, or should be, that *species are unconnected by intermediate forms, while varieties are united into species by the existence of specimens intermediate between them in structure.* This is of course a purely empirical distinction, but it has the merit of being easily understood, workable, not likely to be very differently applied by different workers, and, which is decisive, the only one practicable in the present state of our knowledge. With the advantages of empiricism, however, the method of distinction outlined above combines one of its disadvantages, being somewhat too rigid for universal application. It has therefore to be modified in practice by the judgment of the worker in certain cases; that is to say, in those in which the trend of variation in each of two or more groups of individuals makes it probable that a more extensive series of specimens would show complete continuity, though there be, for the time, a gap between them. In such cases it is legitimate to unite the forms in question as varieties of a single species; though at the time of doing this the uncertainty should be distinctly stated. In point of fact surmises of this sort have repeatedly been justified by later knowledge[3].

[1] In this paper the word *variety* is used to denote an assemblage of individuals (as defined below). *A variation* is a peculiarity of a single individual (though it is often repeated in other individuals, in which case the word may be used collectively). *Variation*—without the indefinite article—is the fact of the existence of variations, and *variability* is the name given to the phenomenon of the occurrence of variation in a species or higher group, or between the like parts of an individual. The adjective *varietal* indicates connection with a variety.

[2] Either in the collection or described by former writers on the species.

[3] It is, indeed, a mere commonplace that many so-called species are mere varieties, to which rank some are degraded every year. In the end it will probably be found that every true species has definite habits and habitat, which have brought about its specific distinctness. It is not, of course, on this account any the less important that varieties should be named and registered.

Two or three more characteristics of varieties remain to be alluded to. In the first place it must be noted that varieties, like species, may be sundered by more than one difference, and that these differences, while they are, no doubt, smaller than those between most kindred species, can be easily paralleled by the latter in many cases, both in kind and in magnitude. Again, though the range of variation within a single variety is generally somewhat greater than that found in most homogeneous species, the latter will sometimes almost, if not quite, equal varieties in that respect. The differences between varieties are often less marked in the young than in old specimens, but this is the case with all the peculiar features of individual organisms. Lastly, there is, in many cases, no ascertained connection between varieties and locality, either geographical or bathymetrical, and they are not known to have any peculiar habits.

As an example of a varietal[1] species we may take *Thalamita admeta* (Hbst.), of whose varieties a key is given below in the second section of this report (p. 202). Here there are six varieties, resembling one another closely (that is, having the same range of variation) in most characters, but capable of separation by means of others, such as the depth of the frontal cleft, the fulness and granulation of the hand (propodite of the first leg), the size of the fourth side-tooth of the cephalothoracic shield; and so forth. These characters, be it noticed, are just such as are used in other cases to separate species of swimming crabs. Again, any two of the varieties may differ in one point only, or in more than one; and the varietal differences are less marked in the young than in old specimens.

With the exception of two new varieties, which appear for the first time in the Maldive collection, but will probably be found ere long in some other part of the range of the *T. admeta*, the geographical distribution of these varieties is practically identical. There would be little doubt of finding all of them in a sufficiently large collection from any part of the Indopacific region. Their bathymetrical distribution, on the other hand, would, if we confined ourselves to the data on p. 203, appear to show clear evidence of limitations of range. For the var. *admeta* was only taken by the Expedition as a littoral form, var. *granosimana* and var. *savignyi* at a depth of not less than 20 fathoms. But var. *savignyi* has been constantly taken elsewhere on the shore, and var. *intermedia* extends down to 30 fathoms, and is also taken on the shore[2], while of the varieties *granosimana* and *admeta* we have certainly not sufficient captures to allow of dogmatic statement.

Again, there is no evidence of any difference in either the habits or the habitat of the varieties. In the Island of Minikoi I was able to recognise, besides the type variety of *T. admeta*, another, differing in the slenderness of the chela, which I suspect to have belonged to *savignyi* (or possibly to *intermedia*, see the footnote to p. 191). Between the type and this variety there appeared to be no difference of habit or habitat. Of course, such differences would probably be hard to find, but the negative evidence on this point is supported by the results of dredgings in the Maldives. These dredgings supply data for recognising the connection, if any exist, between three factors of the environment at least and the organisms dredged. The factors are—the nature of the bottom, the presence or absence of weed, and the presence or absence of currents bringing water from without the

[1] By the term "varietal species" I propose to distinguish a species in which definite varieties have been recognised from a "homogeneous species" in which no such varieties have yet been found.

[2] In this paper the word *shore* will be used to denote that part of the littoral belt which lies between tidemarks, including both the reef and the sand-flats of the lagoon.

reef, as indicated by the nearness or remoteness of passages. In four dredgings var. *granosimana* was taken on a bottom of muddy sand, on another with coarse sand and small rubble, on coarse sand with rubble, and on a hard (rocky) bottom. In two of these dredgings weed was present, in two it was not. The number of captures was not enough to make it possible to come to any conclusion as to the effect of the neighbourhood of passages on the distribution of this variety, but in a similar case—that of the varieties of *T. exetastica*—it is quite clear that this factor is without influence. Var. *savignyi* was only taken twice, but *admeta* and *intermedia*, which were found four and six times respectively, showed no greater tendency to restriction to special environments than did *granosimana*.

2. *The Relation between Varieties and Species.*

Among the Decapod Crustaceans, then, species are paralleled by other assemblages of individuals, known as varieties, which differ from them neither in the nature of their characteristic features nor in the magnitude of these, but only in being connected into groups of two or more by the existence of intermediate individuals. It is hardly possible to resist the conclusion that, in many cases at least, species have arisen from such definite varieties as these by the extinction of the intermediate individuals. And it will be interesting to consider of what nature and origin varieties may be, and what processes may turn them into species.

The orthodox explanation of the origin of varieties such as those we are now dealing with would, no doubt, be that they are produced by natural selection of the variations (generally smaller in degree than those which characterise varieties) which are found within the limits of homogeneous species and varieties. Now there can, of course, be no reasonable doubt that natural selection is at work among the Decapoda, and it is probable that in some cases (as, for instance, in that which Professor Weldon has investigated in *Carcinides maenas*) it brings about transformations of species by accumulating small variations. This is especially likely to be taking place where a variety is locally restricted[1]. But in the case of varieties not so restricted, as we are now using the term, it is very difficult to accept the same view, and that for three reasons.

1. *There is no evidence of isolation* such as is presupposed in the evolution of two or more varieties simultaneously from a single species. And it should be observed that this is the problem now before us, not the replacement of an outworn type of the species under stress of uniformly changing environment over its whole range.

Isolation in the organic world may be of four kinds:

i. "Geographical."

ii. "Habitative"—a name which I propose to give to the separation of allied organisms which, living in the same locality, are nevertheless separated by their habits of life—as one prawn will hide among the branches of corals and another in a sponge, one crab burrow just below high-water mark and another just above, and so on. With this kind of isolation

[1] To these cases the name of "subspecies" might well be confined, leaving that of "variety" for non-local forms such as those now under consideration. The ultimate result of such a process is probably to be seen in genera like *Sesarma*, *Potamon*, and perhaps *Pilumnus*, where large numbers of species, differing in small points from one another, are of local distribution.

may be included that brought about by limitation of an organism to certain zones of depth, or bathymetrical isolation.

iii. "Physiological," due to a greater or less degree of infertility accompanying structural differences between allied organisms.

iv. "Sexual," due to a preference by the members of a species or variety for mating with their own kind.

Local variation is, of course, far from unknown in the Decapoda, but of the class of varieties we are now dealing with one of the most marked characteristics is their independence of geographical limitations. In fact it may generally be safely foretold of a Decapod crustacean that, if one variety be taken in a given locality, any others that may be known will probably also be found there, if only the collection be large enough. In the great majority of cases, if not in all[1], the varieties of the Decapoda are not known to affect *special habits or habitats.* Of course it is also true that very little is known about the habits of the group at all; but this does not justify us in assuming that non-local varieties are adapted to special habits. In a few cases of varietal species which I have examined "in the field," I have been unable to find any evidence of such a phenomenon. We have seen that, in the case of *Thalamita admeta,* there is no sign either of varietal habits or of varietal habitats as far as our present knowledge goes. An even better example is *T. exetastica* Alc., whose three varieties have been taken on every kind of bottom and in varying positions with regard to the passages of the reef. To take another instance, from a different group of Decapods, the porcelain crab *Petrolisthes lamarcki* has four varieties which show no divergence either in habits or in habitat. Regarding bathymetrical isolation there is again no evidence of varietal separation. We have seen that the case of *T. admeta* is somewhat doubtful. That of *T. exetastica* is beyond question in this respect, all the varieties having been taken within a few fathoms of one another in the Maldives. Yet *T. exetastica* is a species with a well-marked specific bathymetrical range, the thirteen recorded captures (including that made by the "Investigator") being all below 26 (or possibly below 30) fathoms.

As to *physiological* and *sexual isolation* in the Decapoda there is no evidence.

2. *There is no evidence of adaptation of varieties to special varietal habits or habitats.* This, which is really an entirely different question from that of isolation, resolves itself into a restatement of the evidence just given. For, so long as hardly anything is known of the adaptation of species by their structure to their specific habitats or habits, it is idle to argue that there is no evidence of the utility of varietal characters. But we do know, or at least are beginning to know, that every species has its specific habitat and habits, to which we conclude, from the few cases that we understand, that its specific characters are adapted. It is therefore quite pertinent to argue that, unless varieties can be shown to have definite habitats and habits, their varietal characters cannot be assumed to be adapted to such circumstances. And it is of just this phenomenon—the existence of varietal habitats and habits—that there is at present no evidence.

3. *There is no clear evidence of intermediate stages in the formation of varietal from homogeneous species.* There are plenty of species in which it is impossible to pick out two

[1] Coutière [*Les Alpheidae*, Paris, 1899] seems to have found at Jibuti examples of habitative isolation among one or two Alpheid varieties, but at present there is always a doubt as to the interpretation put on the term variety.

well-characterised non-local varieties, and again there is a certain proportion in which two or more such varieties are seen. But in all these latter, so far as I have met with them, the varieties are sundered by well-marked gaps. That is to say, in sorting fifty specimens of two varieties, there would not, in my experience, be more than two or three whose position would be doubtful. This is, of course, merely negative evidence, but it would not be right to assume that positive evidence in the opposite direction exists till it be forthcoming[1].

In view of the facts just stated, it is, I think, clear that there are considerable difficulties in the way of explaining the origin of varieties in the Decapoda by means of natural selection. Time and research may remove these difficulties, but it is equally likely that they will not. It will be well, therefore, to consider shortly the alternatives. A Lamarckian view of the question, as compared with the Darwinian, is equally difficult to reconcile with the want of any correlation of varietal characters with the environment, which is implied by the absence of geographical and habitative isolation. There is left, if both these fail us, but one alternative possible. Like smaller variations, those which characterise varieties would appear to be produced by intrinsic forces alone, of whose equilibrium they are perhaps the outcome[2]. But questions so momentous are not to be decided by an examination of one group only, nor by any but those who have made variation a study. In their hands may be left the question "*Are varieties the outcome of inward or of outward forces; does the solution of the problem of their origin lie with Physiology or with Natural History?*"

Turning now to an examination of the ways in which varieties might become species, and assuming that natural selection is the transforming agent, we may consider in what manner it would act. There are two conditions under which natural selection can come into play upon a varietal species. Either the environment may alter, or the species may spread into a new area where the environment is different from that under which it has hitherto been living.

[1] Throughout this article statistics have been avoided, as any attempt to draw exact conclusions in a particular case from less than, say, a thousand specimens would be hazardous. But, to take the first example to hand, out of 36 specimens of the type variety of *Thalamita admeta* collected in the Maldives, two only show characters which caused hesitation as to whether they should be placed with the remaining 34 or with examples of var. *savignyi*. These two were of middle size. One small specimen showed some resemblance to var. *edwardsi*, but its position could not be said to be doubtful.

[2] This alternative, if, as seems probable, it coincide with Bateson's theory of Discontinuous Variation, will receive from that fact an advocacy which will make it worth careful consideration. The chief point in which it amplifies Mr Bateson's theory would seem to be that it is now suggested that discontinuous variations may coincide, and so produce entities still more like species than assemblages of individuals separated on one character only, and that there is no evidence of this coincidence being brought about by natural selection, but on the other hand a possibility of its being due to intrinsic causes (correlation). The same cause, for instance, which produces ridges in one part of the body may, under the different conditions of growth prevailing in another region, make tubercles or granulations, and the swelling of a surface may lessen automatically the relative area of granulation or the height of the granules. Of course very many varieties are separated by one character only, or at all events only one such has yet been detected in them. The origin of such a form is a simpler problem than that of one characterised by two or more special features, and is that which has been chiefly discussed above.

No doubt cases exist of discontinuous variations which do not coincide. But in that case one would probably be more conspicuous than the others, and its use for systematic purposes would cause the others to be overlooked. An examination of a key to the varieties of a species will sometimes reveal such characters of secondary prominence by the fact that it is possible to rearrange the key in two or more ways. In these cases it is easy to see that the key by no means necessarily represents genetic affinities, but merely classifies possible combinations of characters. But I am not here concerned to uphold Mr Bateson's theory, and shall enter no farther into a discussion of this point, which concerns variation, not varieties.

(*a*) Let us suppose the environment to alter. Its effect upon a varietal species might take one of several forms: (i) It might affect all varieties equally, either favourably, unfavourably, or not at all. (ii) It might extinguish all but one. In either of these events the species as a whole would change its characters, but there would be no transformation of a group of varieties into a group of species. (iii) In a species with three or more varieties, in which the extreme varieties are connected (structurally, not necessarily genetically) by intermediate varieties, it might extinguish the intermediate variety or varieties, leaving the extreme ones as separate species. (iv) In a species with two or more varieties, it might affect all or some of the varieties favourably in their most marked form and prove prejudicial to the intermediate individuals between the varieties. By this means it might polish the varieties, so to say, into species.

(*b*) Supposing, on the other hand, the species to migrate into a new environment, either geographical or habitative, the possibilities which we have just discussed again present themselves with the addition of a new factor to determine which of them is to come into play. For clearly either one or more than one of the varieties might migrate, and it is probable that the effect of changed conditions on a single variety would be different from that which they would have on a group of varieties. In the one case we should have the new factor of isolation, in the other this would still be wanting.

But here we are brought face to face with a difficulty due to our lack of knowledge of the reproductive physiology of the Decapoda. The above paragraphs dealing with the effect of a changed environment all presuppose that the varieties breed more or less true, that is, that at least the great majority of the offspring of members of one variety belong to that variety. If, on the other hand, any variety give rise plentifully to all, it is clear that the task of natural selection will be much harder, for it will have to reduce this tendency in the surviving varieties as well as to extinguish the unfitted ones. On this point, however, it is useless to say more in the present state of our knowledge.

[*Note. Jan.* 16, 1902. Since the foregoing was written, Mr Bateson's paper on "Heredity, Differentiation, and other Conceptions of Biology" (*Proc. Roy. Soc.* LXII.) has appeared. It seems that I have reached conclusions somewhat similar to those outlined in the later pages of that paper. What I have called "varietal characters" are probably the same as those which are there called "specific variations," while the "normal variations" are with me "variations within a homogeneous species or variety." If Mr Bateson's conceptions, and the terms by which he designates them, be accepted, a very great advance in Systematic Zoology will be possible. But some confusion is likely to result if either of the terms "varietal" and "specific" be applied to phenomena which are at the base of *both* varietal and specific entity. Would not the word "specifactive" meet the case better?]

II. PORTUNIDAE (SWIMMING CRABS).

1. *General.*

The family Portunidae are distinguished from the rest of the round-fronted (cyclometope) crabs by the adaptation of some of their legs for swimming, to which end these limbs are transformed into flattened paddles. The result is often to confer upon the crabs a power of darting at high speed through the water, which would hardly be credited by those who have not watched them. Corresponding to this mobility they have a thin flattened form of body, enabling them to pass sideways through the water, and a lightness gained at the expense of the protective cuticle. These peculiarities give the swimming crabs a strikingly different bodily form from the heavily-built, slow-moving Xanthids, which is moreover accompanied by an equally marked difference of habitat. The Xanthids are usually to be found on the reef or shore exposed to the full force of the breakers. In this position the lightly-built swimming crabs would be dashed to pieces against the rocks. Their proper haunt is a space of quiet waters, such as the lagoon of a coral atoll, and as these places are, in the tropics, generally bottomed with white or greyish coral sand, on which the crabs lie, and in which they often hide their bodies, they frequently mimic it by their pale greyish colour[1], often in a manner as striking as that in which flat-fish resemble the shingly bottom they live on.

At the same time the swimming crabs are by no means entirely confined to a bottom of coral sand even in the tropics. In deep water, where rocks are not associated with danger, they are found on every kind of bottom in about equal numbers, and here, if they hide, it must be under stones. They even occur, though not so very often, on the reef. But the individuals, found in this position, may possibly have strayed from the lagoon with the outgoing tide. Probably, when more is known about the lives of the species, it will be found that certain of them maintain their existence on the reef by sheltering under stones or in blocks of coral, where if anywhere they are always found, and that others—certainly the bulk of individuals—prefer the lagoon. In their habits these crabs are active and intelligent, escaping capture with cleverness. The lagoon forms usually keep close to the sand and do not rise more than a few feet into the water, but others swim as boldly and strongly as fish.

The bodies of most Portunidae are adorned or protected with sharp thorns or teeth, and it is on such characters as the number and size of these and the shape of the lobed front that the species are generally distinguished, though in most cases enough is not known of their habits to make it possible to say whether, and if so how, these be of use to the animals.

The family is highly variable and varietal and is probably undergoing rapid evolution in many directions.

[1] This colouring would also resemble, though not so closely, that of coral blocks or rubble.

2. *Systematic List.*

Subfamily **Carupinae.**

Genus *Lupocyclus* Ad. and Wh., 1848.

1. *Lupocyclus strigosus* Alc. 1900. Alcock, IV. p. 24.

Dredged in Kolumadulu on a bottom of dead and broken shells in 35 fathoms of water. All previous specimens have been dredged in the neighbourhood of India in 15—58 fathoms.

Subfamily **Thalamitinae.**

Genus *Lissocarcinus* Ad. and Wh., 1848.

2. *Lissocarcinus laevis* Miers, 1886. Alcock, IV. p. 21.

Dredged in South Nilandu on a bottom of hard sand in 36 fathoms of water.

3. *Lissocarcinus polybioides* Ad. and Wh., 1848. Alcock, IV. p. 19.

Dredged in Mulaku on a bottom of mud with weed, in 28 fathoms of water.

4. *Lissocarcinus orbicularis* Dana, 1852. Alcock, IV. p. 20.

This crab lives symbiotically[1] with the teat-fish (*Holothuria nigra*). It hides under or among the tentacles, coming out from shelter at times, perhaps to feed, and crawling all over the body of its host on which it crouches if disturbed. Its dark purple colouring with white spots is protective, resembling the sticky black skin of the teat-fish with grains of coral sand adherent. Paler brown forms live on other Holothurians to whose colour their own is adapted. The other two species taken by the Expedition are roughly speaking sand-coloured, and there is no record of their living symbiotically with other organisms. The females of *L. orbicularis* show a very perfect condition of an arrangement found in various other swimming crabs. That is to say, there is a well-developed brood-pouch formed by a deep sternal hollow surrounded with a fringe of hair and floored by the abdomen, whose sides are also edged with hair. One specimen had many fully hatched zoaeas in this pouch, and it would be interesting to know how long these young remain there, and how much of their development is passed there.

The species was taken on the shore and also dredged. It was found in Minikoi, Hulule, Male Atoll, Furnardu velu[2], Miladumadulu, South Nilandu, and Mulaku.

Genus *Charybdis* de Haan, 1835.

5. *Charybdis* (*Gonioneptunus*) *truncata* (Fabr.). Alcock, IV. p. 67.

The size and shape of the teeth on the antero-lateral edge are not constant. This is probably the reason why the descriptions of different writers do not quite agree. Alcock

[1] The words "symbiosis" and "commensalism" appear to be often used as synonymous, but the latter should obviously be restricted to cases where the food of two associated organisms is of the same nature.

[2] [For definition of this term see p. 155. Ed.]

says that the propodite of the last leg has its hinder edge smooth. It is not serrate, but it bears 4 or 5 minute curved spines, indicated in de Haan's figure of the female.

The species was dredged in depths of more than 28 fathoms, on bottoms of sand and mud, in Haddumati, Kolumadulu, and Mulaku.

Genus *Thalamita* Latr., 1829.

6. *Thalamita prymna* (Hbst.), 1803.

Var. *picta* Stimps., 1859. Alcock, IV. p. 79.

Found sheltering in a coral mass on the outer reef at Minikoi.

Var. *danae* Stimps., 1859. Alcock, IV. p. 77.

Taken on the reef at Minikoi.

It would be interesting to know the difference between the habits of this species and those of the equally common and somewhat similarly built, though quite distinct, *T. admeta*. I am under the impression, though the loss of my Minikoi specimens leaves me somewhat in doubt on this point, that *T. prymna* is a reef crab of a darker, more greenish hue than *T. admeta*, generally found in the neighbourhood of living corals, and perhaps of rather more sluggish habits than the latter. *T. admeta* on the other hand, though also found on the reef, is, I fancy, a lagoon crab of a paler colour, sometimes almost white, fond of lying on the sand, and of extremely active habits.

7. *Thalamita sima* H. M. Edw., 1834. Alcock, IV. p. 81.

There is considerable variation in the depth of the frontal cleft of this species, and same also in the granulation of the under side of the hand. A few specimens came near *T. poissoni*. The absence of spines from the hinder edge of the meropodite is, however, always to be relied on as a distinction between the two. The var. *granosimana* of *T. admeta* tends to approach this species, as will be stated later.

Specimens were dredged in Haddumati, Nilandu, Kolumadulu, Suvadiva, Fadifolu, Felidu, and Mahlos on every kind of bottom below 19 fathoms. Elsewhere it appears generally to have been taken as a shore form. Possibly its small size may have caused it to escape collection on the shore in the Maldives. On its absence from Minikoi no stress can be laid, for the reasons stated in a footnote to p. 191. In dredging, the liability of a swimming crab to capture depends, not on its conspicuousness, but on its powers of swimming, which are usually greater in larger crabs. The small average size of dredged specimens of many swimming crabs is probably due to this.

8. *Thalamita poissoni* Aud. and Sav., 1825. Alcock, IV. p. 81.

The hands of the female (and to a less extent the small hand of the male) have well-marked ridges on the outside and are not full but narrow, like those of *T. admeta*, var. *savignyi*. One male specimen from Suvadiva has the spines on the fore edge of the meropodite of the *cheliped* blunt, as they are said to be in *T. chaptali*. The shape of the frontal lobes and of the frontal notch varies considerably, and some specimens can hardly be told from *T. admeta*, var. *savignyi*, when young, or from var. *edwardsi* of the same species when full grown. In other cases there are traces of scaly markings on the under side of the chelipeds

which recall *T. admeta*, var. *granosimana* on the one hand, and *T. sima* on the other. From the latter species, however, as well as from *T. chaptali*, *T. poissoni* is sharply distinguished, as yet, by the presence, on the hinder edge of the propodite of the last leg, of several spinules, of which there is no trace in *T. sima* or *T. chaptali*. From *T. admeta* it is sundered by its much smaller size.

At present, therefore, it is necessary to keep separate the four forms of *Thalamita* known as *T. admeta*, *T. sima*, *T. poissoni* and *T. chaptali*; but it is far from impossible that they may eventually prove to be all varieties of one species, perhaps in process of separation as independent species.

Dredged in Suvadiva, South Nilandu, Mulaku, Addu, Haddumati, Miladumadulu, Fadifolu, Kolumadulu, and Minikoi, on all kinds of bottoms, in from 7—43 fathoms. Elsewhere has generally been taken on the shore, but the same remarks apply here as in the case of *T. sima*.

9. *Thalamita admeta* (Hbst.), 1803.

T. admeta and *T. quadrilobata*, Alcock, IV. pp. 82—85.

Among the numerous specimens of this very variable species collected by the Expedition, were examples of two varieties hitherto unrecorded. One of these has characters in common with both *T. quadrilobata* Miers and the type of *T. admeta*, having the front of the latter but resembling the former in all other respects. I propose the name of *intermedia* for this form, and have also taken the step contemplated by Alcock, of including *quadrilobata* with *admeta*. The other variety, which I propose to call *granosimana*, resembles var. *savignyi*, but has the under side of the cheliped granular as in *T. sima*, which it also resembles in a rather less flattened body and more arched front than those of *T. admeta*.

The following key includes all the varieties of this species at present recorded:

I. Crest on the basal joint of the second antenna toothed or granular, not spinose.

1. Space between the two lower ridges of the hand (propodite of cheliped) smooth or only very sparsely granular. Fingers shorter than the palm, dactylopodite hooked. At least the big chela of the male deep and full in shape. Median cleft of the front always deep. Fourth side-tooth of carapace usually quite vestigial.

i. Outer surface of hand more or less granular; ridges strongly developed.

Var. A, *admeta* (Herbst.), 1803.

ii. Outer surface of hand smooth; ridges slight.

Var. B, *edwardsi* Borradaile, 1900.

2. Space between the two lower ridges on the hand strongly granular. Fingers as long as palm, straight. Chelae slender in shape. Median cleft of the front often shallow. Fourth side-tooth of carapace small, but not vestigial.

i. Under side of hands smooth.

Var. C, *savignyi* A. Milne-Edwards, 1861.

ii. Under side of hands granular.

Var. D, *granosimana* n.

II. Crest on basal joint of second antenna with three large spines.

1. Front two-lobed.

Var. E, *intermedia* n.

2. Front four-lobed.

Var. F, *quadrilobata* Miers, 1884.

Admeta was taken on the shore in Minikoi, Goidu, Fadifolu, and S. Mahlos; *intermedia* on the shore in Goidu and Fadifolu, in 5 fathoms at North Male and in 30 fathoms at Haddumati; *granosimana* in 20—43 fathoms on bottoms of varying description in Mahlos, Kolumadulu, South Nilandu and Suvadiva; and *savignyi* in 23—28 fathoms at North Male and Mahlos. The latter variety was probably also seen at Minikoi.

Admeta, savignyi and *intermedia* are, to the best of my knowledge, found both on the reef and in the lagoon[1]. With them go probably *edwardsi* and *quadrilobata*. *Savignyi* and *intermedia* certainly, and probably also the other three, extend from the shore down to 30 or 40 fathoms at least. *Granosimana*, which shows features which tend to ally it with *T. sima*, has, like the latter species, been found only in deep water in the Maldives. If this be a real and not an apparent limitation (see above p. 201), the same cause is probably at work in both cases, and *granosimana* very likely exists elsewhere on the shore with *T. sima* and *T. poissoni*. In that case it is probably an incipient species in a somewhat earlier stage than *T. sima* and *T. poissoni*. On the other hand it may be a genuine local subspecies.

10. *Thalamita exetastica* Alc. 1900. Alcock, IV. p. 86.

The collection contains a number of specimens which are at least closely allied to this species and may all be for the present classed as varieties of it. Some of them approach very closely to Alcock's definition, but there is one point in which all fall somewhat short. This is in the squamiform markings on the chelipeds, which never completely cover the limb but are always replaced to a greater or less extent by more rounded granulations on the upper side, and are often wanting over a part of the lower side.

Three varieties are present:

1. Var. A. Typical, that is, agrees with Alcock's definition in all points (except the granulation of the chelipeds as above).

2. Var. B, *spinifera*. Differs from the type in having a varying number of spines on the hinder edge of the propodite of the last leg. In this point it approaches *T. investigatoris*, Alcock, 1900.

3. Var. C, *macrodonta*. Has no spines on hinder edge of last propodite, but differs from type in that:

(i) The last side-tooth is nearly as large as the third and projects somewhat more than the rest. Fourth tooth rudimentary.

(ii) The median frontal lobes are distinctly narrower than the submedian. About 1 : 2 in the Kolumadulu specimen, and 2 : 3 in the Suvadiva specimen.

In both these respects the variety approaches *T. investigatoris*.

[1] See footnote to p. 191.

Var. A was dredged in 30 and in 37 fathoms in Suvadiva, on a rough stony bottom and on the hard smooth bottom of a passage.

Var. B was dredged in Suvadiva, Kolumadulu, South Nilandu, Haddumati, Mulaku, and Felidu in 30—45 fathoms on every kind of bottom.

Var. C was dredged in Suvadiva and Kolumadulu in 34 and 35 fathoms on bottoms of rubble and broken shells respectively.

It seems not unlikely that the dredgings of the "Investigator" and of Mr Gardiner's Expedition have revealed a new and highly varietal species of *Thalamita* in deep waters near India, of which *T. exetastica*, var. *spinifera*, var. *macrodonta*, *T. investigatoris* and *T. imparimanus* are but varieties. The habitat of this species is probably in moderately deep water only. Allied to it, but separated from it by the form of the chelipeds and their equality in the male, is the species next described of which the only known specimen has been taken on the littoral.

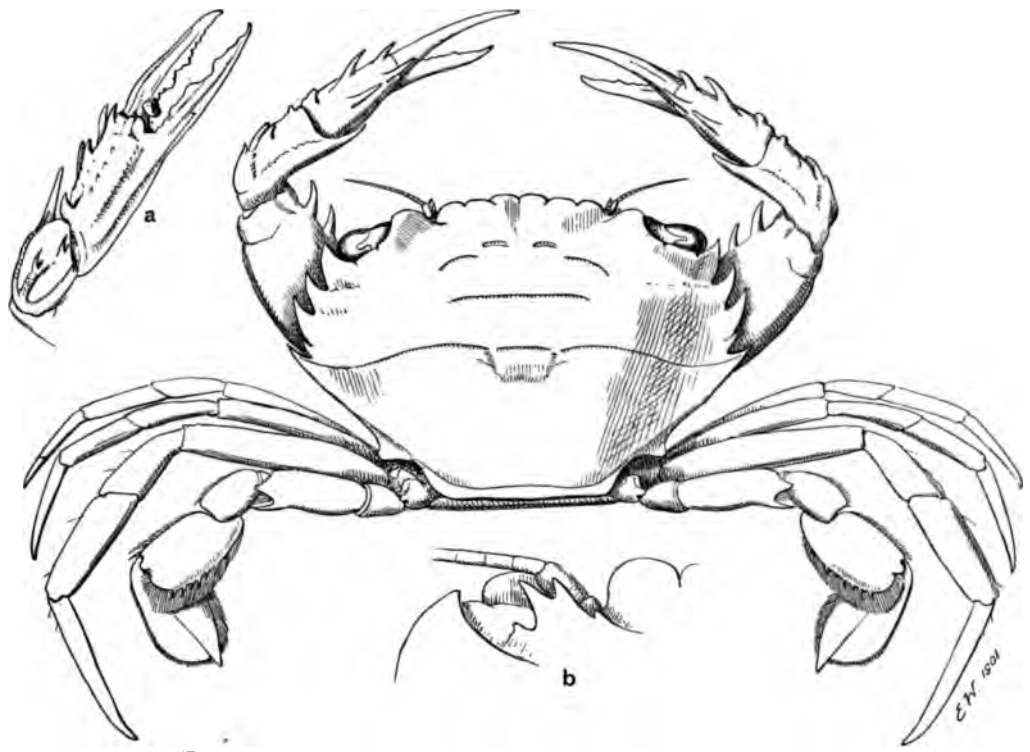

FIG. 35. *Thalamita tenuipes*; *a.* outside of chela, *b.* base of antenna.

11. *Thalamita tenuipes* n. sp.

Closely allied to *T. imparimana* Alc. 1900 (IV. p. 87), but separated from it by the following characters:

(i) Basal joint of antenna has a short crest consisting of two large teeth fused at their bases.

(ii) Chelipeds of male equal, smooth, with a few scattered warts and scanty hairs. Outside the wrist are two ridges, and three spines, at the inner angle one spine. Outside

the hand two distinct ridges, with another less distinct above them; on the upper side two pairs of spines. Fingers as long as palm, slender, hooked at tip, grooved within and without.

(iii) Line between 6th and 7th abdominal terga very slightly concave.

(iv) Habitat the shore (?).

Length 10 mm.; breadth 13 mm.

Colour in spirit, ochreous yellow.

One male from Goidu, Goifurfehendu Atoll.

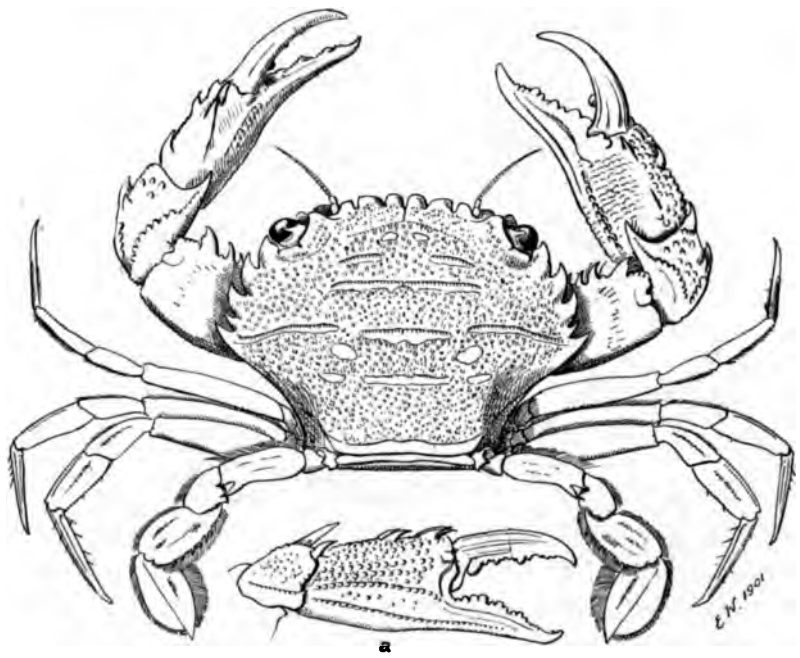

FIG. 36. *Thalamita gardineri*; *a.* outside of chela.

12. *Thalamita gardineri* n. sp.

The *exetastica* group of *Thalamita* approach *Charybdis* in some respects. The present species is allied by its features both to *Charybdis* and to the *exetastica* group. From the latter it is sundered by the following characters:

(i) The transverse ridges of the carapace are disposed as in *T. exetastica* but are rather more prominent than in the type variety.

(ii) The antero-lateral edge slopes outwards, making a greater angle with the middle line of the body than in *T. exetastica.*

(iii) The median frontal lobes are distinctly narrower than the submedian (2 : 3), and on a lower plane than, though not overlapped by, the latter.

(iv) The last side-tooth projects much more than the rest, and is as long as the 2nd or 3rd, though not so broad. The 4th side-tooth is small, but not rudimentary. There is no small tooth at the base of the first side-tooth.

(v) The chelipeds of the adult male are almost absolutely equal. Transverse squamiform markings are almost wanting. The upper side of the hand is covered with rounded granules, but on the inside squamiform markings remain.

(vi) There are about 10 spines on the hinder edge of the last propodite.

Length of longest specimen (♂), 13 mm. Breadth of same specimen, 17 mm.

Colour in spirit, sandy mottled with reddish.

Taken in Minikoi, sheltering under stones on the reef. This species is transitional to *Charybdis* (Goniosoma), but is separated from that genus by having only five side-teeth. The outward trend of the antero-lateral edge is a character which makes its position in the genus *Thalamita* somewhat doubtful.

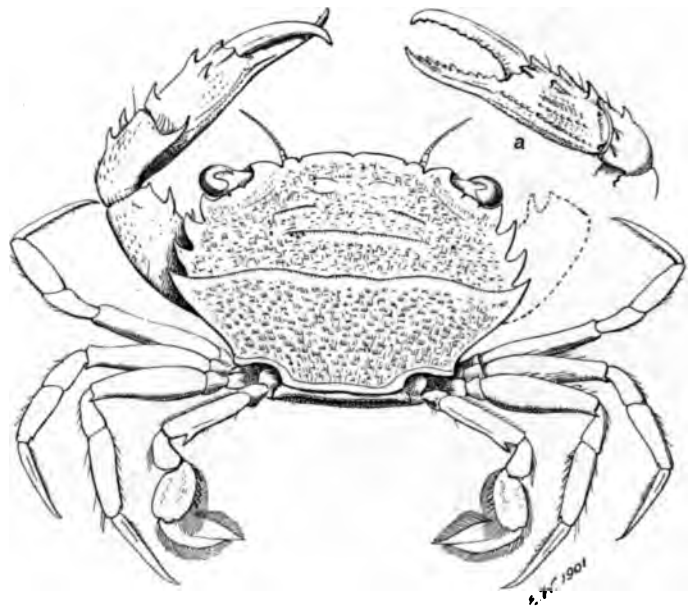

FIG. 37. *Thalamita cooperi*; *a*. outside of chela.

13. *Thalamita cooperi* n. sp.

Closely allied to *T. invicta* Thallw. 1890[1], of which it is possibly only a variety. It differs from Thallwitz' species however in the following points:

(i) The fourth side-tooth is wanting, and not merely vestigial as in *invicta*.

(ii) The outer side of the hand bears the usual five spines, instead of only three.

The front is lobed (excluding the orbital lobes), the middle lobes being the widest and somewhat recalling the frontal lobes of *T. admeta*. There are four side spines including the orbital angle, the fourth of those usually present being lost. The antennal ridge is granular. On the outside of the hand are the usual five spines and three granulated ridges. The fingers are shorter than the hand. The last propodite bears about half-a-dozen spinules.

[1] Thallwitz, *Abh. Zool. Mus. Dresden*, 1890—1891, No. 3, p. 46.

Taken at Goidu, Hulule and Minikoi, on the shore in each case. At the latter island it was sheltering in a coral block on the outer reef.

I have called this species after my friend Mr C. Forster Cooper, who was a member of the Expedition.

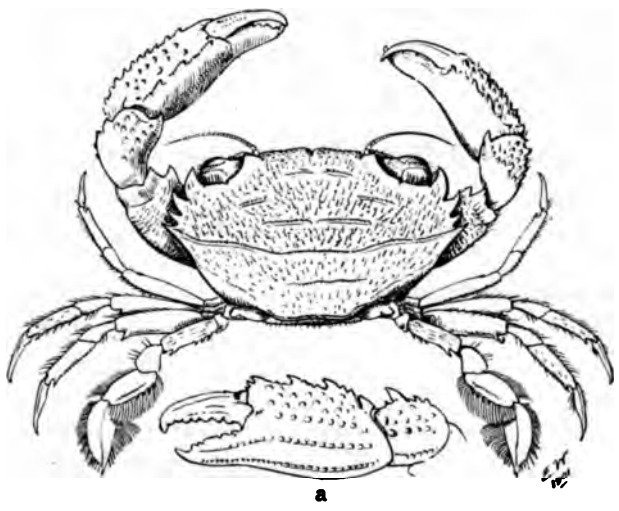

FIG. 38. *Thalamita pilumnoides*; *a*, outside of chela.

14. *Thalamita pilumnoides* n. sp.

Diagnosis: "A *Thalamita* with the body and limbs very hairy; the ridges of the back much as in *T. admeta*; the front bent downwards, slightly arched, and bilobed, the angles of each lobe being slightly produced; the inner supraorbital lobes nearly straight, sloping backwards and inwards, less than half the width of the frontal lobes; side-teeth four in number (including the orbital tooth), the third being the smallest; the hinder edge of the carapace concave, forming a gentle curve with the side edge; the sixth abdominal segment of the male broader than long; the basal joint of the antenna about equal to the orbit in width, its crest with four blunt teeth; the chelipeds stout, unequal (in ♂ at least), with three granular ridges on the outside of the hand, the areas between the ridges smooth, the under side smooth, the upper side covered with sharp tubercles, a row of three teeth along the inner edge of the upper side and one tooth at the articulation with the wrist, the fingers shorter than the palm, the wrist with one spine at the inner angle and three smaller ones on the outside, while the upper side bears some granules as on the hand, the arm with a series of teeth on its fore edge, diminishing from without inwards, and part of the upper surface granular; a spine on the hinder edge of the last meropodite and two or three spinules on the hinder edge of the last propodite."

Length, 4 mm.; breadth, 6·5 mm.

Colour in spirit, pale yellow with minute green spots in places, especially on the front.

One male from a small shoal in the middle of the lagoon at Minikoi.

Subfamily **Portuninae.**

Genus *Neptunus* de Haan, 1833.

15. *Neptunus* (*Achelous*) *granulatus* (H. M. Edw.), 1834. Alcock, IV. p. 45.

Taken in Haddumati, Suvadiva, Felidu, South Nilandu, Male, Kolumadulu, Miladumadulu and Mahlos from 0—43 fathoms on every kind of bottom. Not recorded from a tidal reef.

16. *Neptunus* (*Hellenus*) *longispinosus* (Dana), 1852. Alcock, IV. p. 40.

Taken in Minikoi, Hulule, Mahlos, Male, South Nilandu, Kolumadulu, Haddumati and Miladumadulu in 2—4 fathoms on every kind of bottom. Not recorded from a tidal reef.

17. *Neptunus* (*Hellenus*) *tuberculosus* H. M. Edw. 1861. Alcock, IV. p. 42.

Taken in Haddumati, Kolumadulu, and Felidu in 22—40 fathoms on bottoms of sand with weed or rubble.

18. *Neptunus* (*Hellenus*) *hastatoides* (Fabr.), 1798. Alcock, IV. p. 38.

In all the specimens the middle lobes of the front are distinctly shorter than the others. Taken in South Nilandu and Mulaku in 19—30 fathoms on hard and on muddy bottoms respectively.

19. *Neptunus* (*Hellenus*) *tenuipes* (de Haan), 1835. Alcock, IV. p. 42.

The last side-spine in nearly all the specimens is considerably more than three times the length of any of the others, which is the proportion given by Alcock, but it varies in length a good deal.

Taken in Mulaku, Haddumati, Felidu, South Nilandu, and Suvadiva in 28—40 fathoms on sandy or muddy bottoms.

CHAETOGNATHA,

WITH A NOTE ON THE VARIATION AND DISTRIBUTION OF THE GROUP.

By Leonard Doncaster, B.A., *Scholar of King's College, Cambridge.*

(With Plate XIII, and Text-figures 39 and 40.)

Among the pelagic organisms, collected by Mr Stanley Gardiner's Expedition in the Maldive Archipelago in the years 1899 and 1900, were considerable numbers of Chaetognatha. They were fished chiefly at night, in moderate depths, and were preserved directly in 4 per cent. formalin. They are divided into two parts, viz. some were collected between Dec. 10 and Jan. 10, and the rest in April. Those obtained in the winter were much more abundant both in individuals and species, the number of specimens submitted to me being about 900 in the winter months compared with rather over 250 in April.

In classifying the group I have followed Langerhans ("Wurmfauna von Madeira," *Zeitschr. wiss. Zool.* Bd. xxxiv. p. 132, 1880) and Strodtmann ("Systematik der Chaetognathen," *Archiv Naturgeschichte*, Jahrgang 58, Bd. i. p. 333, 1892), and have used the names *Sagitta*, *Spadella* and *Krohnia* in the sense which they have defined, viz.

Sagitta forms with two pairs of lateral fins, and two rows of teeth;

Spadella with one pair of lateral fins on the tail segment only, and two rows of teeth;

Krohnia with one pair of lateral fins extending on the trunk and tail, and one row of teeth.

The Chaetognatha from the Maldives include several species well known from European waters, and others which have been procured only from the American coast or from Japan, but a considerable proportion (6 species out of 15) appear to be undescribed. *Sagitta* is much the most abundant genus, but *Spadella* is represented by one moderately common species, while only two specimens of *Krohnia* were found.

In a Note at the end of the "List of the Species" I have added the description of a new species, found by the late Mr F. P. Bedford at Singapore.

I. LIST OF THE SPECIES.

I. Genus **Sagitta** Slabber.

1. *Sagitta enflata* Grassi.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 348, 1892.

This species is very abundant both in winter and in April, making up perhaps fifty per cent. of each collection. It agrees with Grassi's description in most points; the tail segment is however rather shorter in proportion to the trunk, and the teeth are sometimes more numerous. Exactly the same differences are described by Aida (*Annot. Zool. Jap.* Vol. I. p. 13, 1897) between the *S. enflata* found in Japan and those of European waters.

This species has been hitherto recorded from the Mediterranean, Madeira and Japan.

2. *Sagitta magna* Langerhans.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 343, 1892.

Fairly abundant in the winter, but not found in April. Only a few specimens reached a length of 3 cm. Did not differ in any points from Grassi's and Strodtmann's descriptions.

Recorded hitherto from Madeira and the Mediterranean.

3. *Sagitta tricuspidata* Kent.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 342, 1892.

A rather scarce species in the winter, and not found in April. It is the largest species found, some specimens attaining a length of nearly 4 cm. In shape it is like *S. magna*, but slightly narrower, and while the posterior fins of *magna* are nearly semicircular, those of *tricuspidata* are broader near their posterior ends. The ovaries are long and slender, and may extend to the front end of the anterior fins; the longest observed were 1·5 cm. in length. Hooks 4—8, anterior teeth 3, posterior 1; but in several specimens, making up a large proportion of the whole number, there were 2 anterior and either 2 or 4 posterior teeth. The posterior teeth are attached to a cuticular bar which bears a number of rounded projections. Such projections are commonly found in other Sagittas, corresponding in number and position with the teeth, and are in some cases sharply pointed, and in this species, although the teeth are reduced to very few, the projections remain, but are rounded off. A similar condition exists in *S. magna*. The corona ciliata is short, on the head and neck.

This species has very few distinguishing characters; it is separated from *magna* chiefly by the absence of the very long moveable teeth in the anterior row, and from *hexaptera* by the small number of posterior teeth, but when the latter are as numerous as four, it becomes difficult to separate them with certainty. The teeth seem to have been reduced, and are at present very variable, but the typical number for the species is three anterior and one posterior.

Recorded from the Pacific, the Atlantic, the Mediterranean and the Indian Ocean.

4. *Sagitta serratodentata* Krohn.

Strodtmann, *Archiv Naturgeschichte*, Jahrg. 58, Bd. I. p. 347, 1892.

A moderately common species both in winter and spring. Some specimens had as many as 18—20 posterior teeth and 10 anterior, instead of 12 and 8 respectively as are normal in European waters.

Hitherto recorded from the Mediterranean, the Atlantic, and Japan.

5. *Sagitta hispida* Conant.

F. S. Conant, *Johns Hopkins Univ. Circ.* Vol. XIV. p. 77, 1896, and XV. p. 82, 1896.

This species was rather scarce in the material collected in the winter, but in that obtained in April it was very abundant. It is characterized by the thickness and solidity of the body-wall, the thickened ectoderm behind the head, the intestinal diverticula in the neck, and the great number of tactile prominences. The teeth in the specimens from the Maldives were sometimes more numerous than in Conant's description; Aida mentions the same fact in specimens from Japan. Corona ciliata long and waved; in one specimen I found it divided into two parts, an anterior and a posterior.

Described previously from the Atlantic coast of America, the West Indies, and Japan.

6. *Sagitta regularis* Aida. (Plate XIII, fig. 7.)

T. Aida, *Annot. Zool. Jap.* Vol. I. p. 17, 1897.

Occurred in small numbers in the winter. This species is very small, rarely more than 5 mm. The tail is one-third of the length of the whole. The fins are narrow, semi-elliptical, and have rays extending to the base. The tail fin and the posterior lateral fin both touch the vesiculae seminales, which are small. The ovaries extend to the anterior paired fins. The epidermis is thickened through the whole length of the animal, but very much so behind the head, so that there is no neck. The number of tactile prominences is very large, and they are arranged with great regularity. The intestine has diverticula at its beginning. Hooks 7, anterior teeth about 4, posterior about 6. Corona ciliata rather long, waved, with a constriction in the middle. It is shorter than that of *S. hispida*, and lies entirely on the trunk.

Hitherto recorded only from Japan.

7. *Sagitta flaccida* Conant.

F. S. Conant, *Johns Hopkins Univ. Circ.* Vol. XV. p. 82, 1896.

Only one specimen of this species was found, and it occurred in the collection made in April. The species resembles *S. enflata* very closely, but differs in the form of the teeth. There are seven or eight anterior and 10—12 posterior teeth, and they are longer and more slender than in *enflata*, and the inner ones, especially of the anterior row, are much longer than the outer.

Described only from the Bahamas.

8. *Sagitta robusta* nov. sp. (Plate XIII, figs. 1 *A*, 1 *B*.)

This species is abundant in the material collected in winter, but scarce in that obtained in April. It is characterized by the great thickness of the body-wall, especially of the longitudinal muscles.

The length of mature specimens is 1·6 cm. of which the tail segment makes up one-fourth. The head is broad; the anterior fin is as long as the posterior, but narrower, its front end is opposite the posterior end of the abdominal ganglion. Both posterior lateral fins and tail fin reach the vesiculae seminales. The fin-rays do not extend quite to the base of the fins. The epidermis is thickened behind the head. The corona ciliata is long and narrow, beginning in front of the eyes just behind the brain, and is in shape an elongated ellipse, without the cross-shape found in *S. bipunctata*. There is a pair of diverticula at the beginning of the intestine, like those in *S. minima*. The ovaries are extremely long, and extend in fully mature specimens to the anterior transverse septum, so that the coelom of the trunk becomes almost obliterated. The vesiculae seminales project somewhat. Hooks usually 8, with very small points; anterior teeth 9, posterior 10—14.

I have found this species also among Chaetognatha collected at Singapore.

9. *Sagitta ferox* nov. sp. (Plate XIII, fig. 2.)

A species closely resembling *S. robusta*, but distinguished by several constant differences. It is less abundant than the latter, and did not occur in the April collection.

The body-wall is very thick, with powerful muscles. The tail segment is rather more than one-fourth of the whole length, which is about 1·2 cm. The fins are almost as in *S. robusta*, but the posterior does not quite reach the vesiculae seminales, which project only slightly. The epidermis is slightly thickened behind the head. There are intestinal diverticula as in *S. robusta*, and the ovaries are extremely long, as in the latter, but they do not quite reach the front end of the trunk-cavity. Hooks 5, or sometimes 6, very thick and powerful, with rather blunt points; anterior teeth about 6, posterior 10, with blunt points and rather broad.

As will be seen from the above description, this species differs very slightly from the last, and should possibly be classed with it. In some points, however, there is a constant difference. There are never more than 6 hooks in *S. ferox*, and there are usually only 5, while in *S. robusta* there are 7 or 8, and the hooks of *ferox* are thicker and have larger point-pieces than in the other species. The teeth of *ferox* are also thicker and rather fewer in number. In no specimen was the corona ciliata found complete in *ferox*, but from the traces that remain it seems to resemble that of *robusta*. When preserved in formalin *ferox* always has a faint pink colour, while *robusta* is white or yellow, and is rather less opaque.

10. *Sagitta gardineri* nov. sp. (Plate XIII, figs. 5 *A*, 5 *B*.)

A moderately abundant species in the winter collection.

Length 2·5 cm. Body thick and transparent, resembling that of *S. magna*. Head broad and short. Tail segment one-fifth of length of whole. Fins like those of *S. magna*; the rays do not quite reach the base. Ovaries when mature rather long, extending to the posterior end of the anterior fin; they are thicker and shorter than in *S. magna*, but proportionately longer than in *S. enflata*. Vesiculae seminales spherical, placed at the front

end of the tail fin. Corona ciliata entirely on the head; pear-shaped, with the narrow end lying just behind the brain, in front of the eyes. Hooks 8—10; anterior teeth small, about 10; posterior larger, pointed, varying from 12 to 16.

This species is intermediate between *S. hexaptera* and *enflata* in size and in the form of the ovaries, and it differs from both in the larger number of teeth. Although it is closely connected with these two species, yet the differences are so constant that there can be no doubt of its distinctness.

11. *Sagitta pulchra* nov. sp. (Plate XIII, figs. 4 *A*, 4 *B*.)

A moderate number of this species occurred both in the winter and spring collections.

Its length is 2 cm., of which the tail segment makes up one-sixth. The body is slender, with a thin body-wall, so that this species is intermediate between the large, inflated, and the smaller muscular types of *Sagitta*. The head is small, and the epidermis somewhat thickened behind the head. The anterior fin begins at the abdominal ganglion, and is rather long, so as to be separated by a short distance only from the posterior. The front half of the anterior fin is very narrow and has no rays; the posterior part is rather wide. The posterior fin is like the anterior in shape, but the part without rays is shorter and that with rays wider. The rays do not extend quite to the base.

The ovaries are rather long and slender, the vesiculae seminales small. The whole of the tail coelom is filled with developing spermatozoa. The corona ciliata is moderately long; it begins in front of the eyes and rather more than two-thirds of its length is on the trunk; it is narrow and its sides parallel. Hooks 6, rather curved and slender; anterior teeth about 6, posterior about 10.

This species is of interest in combining the characters of two groups of *Sagitta*, viz. the larger species, which have a thin body-wall, short corona and in which only part of the tail coelom is filled with developing sperm; and secondly the smaller species with thick body-wall, long corona and tail full of sperm-morulae.

12. *Sagitta polyodon* nov. sp. (Plate XIII, figs. 3 *A*, 3 *B*.)

Found in fair abundance in both winter and spring.

This species is superficially very like *S. serratodentata*. Its length is about 1·2 cm., the tail one-fourth of the whole. The shape is that of *serratodentata*. The fin-rays spring from the base of the fins. The ovaries are long, extending to the anterior fins. The vesiculae seminales are rather large and projecting. The hooks are 6—7, with no serrations; anterior teeth 9—10, posterior 26; they are slender, truncated at the end, with small processes. The corona ciliata is long and rather wider just behind the neck than elsewhere.

This species is distinguished at once by the great number of its teeth, which are more numerous than in any other known species. It resembles Béraneck's description of *S. bedoti*[1] in many ways, but differs in having a corona, in the length of the ovaries, and the greater number of teeth. Since Béraneck described *S. bedoti* from preserved specimens, in which the corona is often destroyed in one species while well-preserved in

[1] E. Béraneck, "Chétognathes de la baie d'Amboine," *Rev. Zool. Suisse*, Vol. III. p. 147, 1895.

others, it is possible that in this point he was mistaken; but, since the absence of the corona is a definite part of the diagnosis of *S. bedoti*, the present species cannot be identified with it.

13. *Sagitta septata* nov. sp. (Plate XIII, fig. 6.)

Moderately common both in winter and in spring.

It is a small species, generally less than 1 cm. The tail segment is a third of the whole. The fins are narrow, especially the anterior. There is no epidermal thickening behind the head, but the body-wall as a whole is thicker in the posterior part of the trunk than anteriorly. There are intestinal diverticula like those of *S. minima*. The vesiculae seminales are very small. The ovaries are long, extending to the ventral ganglion, and the ova have a very curious appearance in fully adult specimens. They become pressed together so that they are flattened anteriorly and posteriorly, and the flattened faces have the appearance of septa dividing the trunk into a series of compartments on each side.

In no specimen was the corona well preserved, but it could be seen from the fragments remaining that it lies both on the head and on, at least, the beginning of the trunk. Hooks 6—8, anterior teeth 6—8, posterior 13—16, rather narrow and pointed.

The most prominent characteristic of this species is the peculiar structure of the ovaries (Plate XIII, fig. 6 and Text-fig. 39). The eggs appear to have their shells well developed, and the "septa" are due to the shells of two eggs being pressed together. In section it appears that when the eggs assume this condition they are already in the oviduct, which is greatly dilated, for when followed back the cavity containing the eggs is found to open at the usual pore of the oviduct; this view is supported by the fact that the large eggs lie at the outer sides of the ovaries, next to the body-wall, and that no other oviduct is visible, and further that the usual germinal epithelium appears between the large eggs and the alimentary canal. The animals appear to be undergoing histological degeneration, for the alimentary canal has lost its lining cells for the most part, and through the greater part of the body is much reduced in size. A condition comparable with this is frequently found in *S. minima*. A very similar arrangement of the eggs occurs in a fully adult *Krohnia pacifica* in Mr Gardiner's collection, so that it is not quite peculiar to *Sagitta septata*.

FIG. 39. Transverse section of *Sagitta septata* in the region of the ovaries. The ripe eggs are represented by oval bodies (dotted) lying in spaces which are probably the enlarged oviducts. The germinal epithelium is seen lying at the inner side of each of these spaces, connected with the alimentary canal by a mesentery.

II. Genus **Spadella** Langerhans.

14. *Spadella draco* Krohn.

Strodtmann, *Archiv für Naturgeschichte*, Jahrg. 58, Bd. I. 1892, p. 356.

This species was plentiful in the winter but did not occur in the summer. It agrees in every way with the published descriptions. I found a number of specimens in which the remarkable parenchymatous tissue was entirely absent, and was at first inclined to regard them as a new species, but afterwards found some in which part of the parenchyma

remained, showing that it had become detached during preservation or in transit. Some of the best-preserved specimens have a bright yellow colour in formalin, while others are colourless.

This species has been previously recorded from the Mediterranean, both sides of the Atlantic, Java and Japan.

III. Genus **Krohnia** Langerhans.

15. *Krohnia pacifica* Aida.

T. Aida, *Annot. Zool. Jap.* Vol. I. p. 19, 1897.

Only two specimens of this species were obtained; one in the winter and one in the April collection. It is only 7 mm. in length, but the ovaries show it to be mature. In the specimen taken in April the latter had large eggs (text-fig. 40), pressed together as described above in *Sagitta septata*. The tail is a third of the whole length. Both tail-fin and lateral fin meet the vesiculae seminales, which are ovoid. The tactile prominences have very long bristles. Hooks 9, pointed, with very small end-pieces. Teeth 13, very long; the row of one side meets that of the other side. The eyes are very near together.

There can be no doubt that this is the *Krohnia pacifica* described by Aida; the teeth are slightly more numerous, and the green colour which he mentions is not visible in preserved specimens. He describes the mouth as a transverse slit, but this appears to me to be due to a sort of lip overhanging the mouth anteriorly; the true mouth is as usual longitudinal.

Previously described only from Japan.

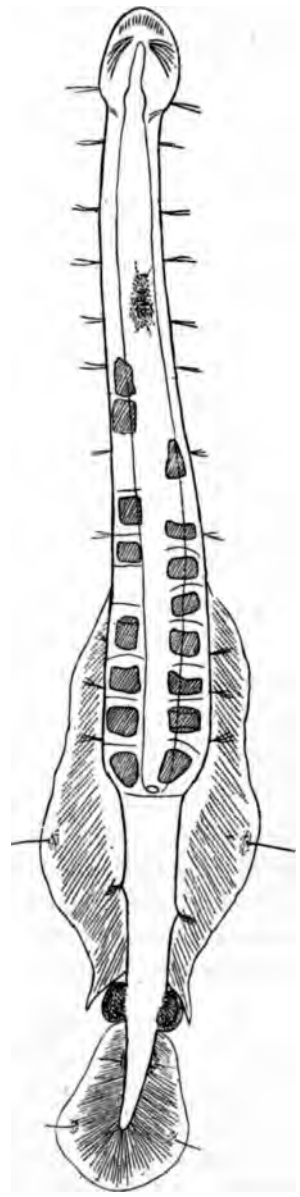

Fig. 40. *Krohnia pacifica*. A specimen taken in April, which has a number of ripe eggs on each side arranged with their shells in contact, giving the appearance of transverse septa. These eggs, as in *Sagitta septata*, are probably in the oviduct.

[Note. On some Chaetognatha from Singapore.

I include here the description of a new species of *Sagitta* obtained by the late F. P. Bedford at Singapore. It was accompanied by a few specimens of *S. enflata* and *S. robusta*. There was only one specimen, which is not fully mature; the condition of the ovaries however shows that it is not very young.

Sagitta bedfordii nov. sp.

Very small; an individual apparently nearing maturity, measures only 3·5 mm. Tail one-third of whole. Fins narrow, with rays springing from the base and placed unusually far apart. Corona ciliata imperfectly preserved, but lying both on head and trunk, and apparently short and pear-shaped. Body-wall thick, with epidermal thickening behind the head. Hooks 10, anterior teeth 2, posterior 2, all, especially the anterior ones, long, narrow and pointed, like those of *S. magna*.

The number and shape of the teeth is sufficient to distinguish this species at once from all the other small species.]

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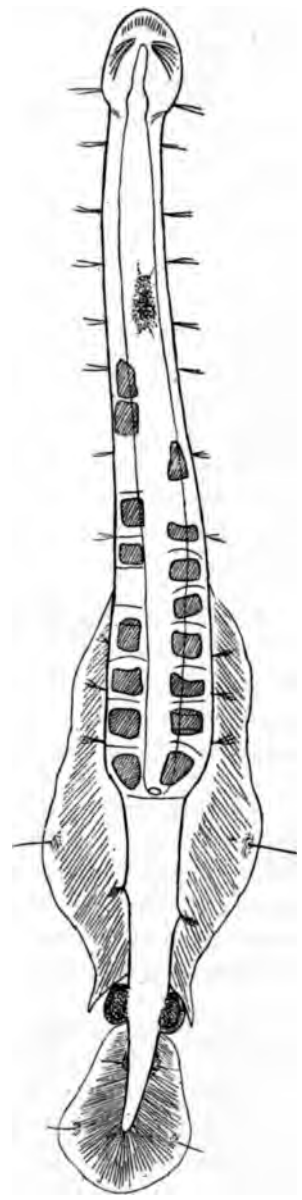

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The number and shape of the teeth is sufficient to distinguish this species at once from all the other small species.]

II. VARIATION AND DISTRIBUTION OF THE GROUP.

The examination of the specific characters and the geographical distribution of the Chaetognatha leads to several points of interest. In the first place, it is found that most species are world-wide in their distribution, and are obtained in almost all the warmer seas; only a few species have been observed in very limited areas, and since *Sagitta flaccida* and *S. regularis*, which had hitherto been recorded only from the West Indies and Japan respectively, have now been found also in the Indian Ocean, it seems probable that some, if not all, the remaining local species will be known eventually to have a wider range.

Individuals of the same species have as a rule the same characters in whatever part of the world they occur, but there are a number of exceptions to this rule; for example, the *S. serratodentata* from the Maldive Group had usually a greater number of teeth than those of the Mediterranean, and Aida records the same fact in respect of several species from Japan. But the characters, which are used to distinguish the species of the Chaetognatha, are very variable in themselves, so that examples from the same locality differ considerably from one another, and it is sometimes a matter of difficulty to determine these species with certainty; for example, the individuals described above as *S. tricuspidata*, which have an arrangement of teeth different from that of the type, might be referred to *S. hexaptera*, in which the teeth were fewer than the normal, and so in other cases.

In fact, it almost seems that the species in the Chaetognatha are not very definitely fixed, but graduate into one another to some extent, although they can be separated into several groups, which are very distinct; for example, *Sagitta hexaptera*, *S. tricuspidata*, *S. magna* and *S. lyra* form a well-marked group of large species, which can be separated at a glance from the type represented by *S. hispida* and *S. regularis*.

The question of species in the Chaetognatha is an interesting one from the point of view of evolution, for in most seas a great number of individuals of various species are found together but all having, as far as we know, similar habits and living mingled together. Geographical isolation or differences of habitat apparently do not exist, and probably most species breed through the greater part of the year, so that there can be no separation by differences of breeding season.

In many instances two species, living together, are so closely allied that it is very difficult to distinguish them, in which case it seems hardly possible that the separation can have been due to natural selection. Possibly the great variety of Chaetognatha found together, all living under the same conditions and with similar habits, may be best explained by supposing the species to be very ancient, and that the different species have arisen in different parts of the world and have become spread by currents or other means of dispersal, until they are found in all the seas where the temperature is sufficiently high. The characters by which the species are distinguished, such as hooks, teeth, proportions of the body and fins, etc., are very variable within certain limits, as has been shown above. If, then, a part of the ocean became partly or wholly separated from the rest by geological changes, in the course of time this variability would undoubtedly cause the fauna, so cut off, to become different from the remainder, and, when they again became intermingled, they would be classed as different species. The Chaetognatha offer this problem in a

peculiarly prominent manner, for there are few other groups of animals of which as many as ten or even more species of one genus are found together in exactly the same environment.

The question of the nature and extent of the variation in each species is also of interest, for there are indications that the characters commonly relied upon as distinctive may sometimes be very untrustworthy. It has been pointed out how in some species local races exist with slightly different characters, as in the case of *Sagitta serratodentata* and *S. hispida*, but some species are markedly variable in the same locality. For example, besides the variation in number of the teeth in *S. tricuspidata* mentioned above, it was found that while the typical number of hooks is 8, one specimen had only 4, another 5, and others 7 on each side.

I observed a more remarkable case of this at Naples, which possibly indicates that the hooks are lost to some extent at maturity. The species in question was *Sagitta lyra*, which Grassi in his monograph (*Fauna et Flora des Golfes von Neapel*; I Chetognati) describes as being very rarely found sexually mature, while immature specimens are comparatively common. At Naples during the early spring of 1901 immature specimens were frequent in the "Auftrieb" from no great depth, and many were of considerable size, *e.g.* as much as 28 mm. with only most minute rudiments of ovaries and testes, and no trace of genital ducts. In April, however, a number of specimens were caught in the neighbourhood of Capri at depths of 400 and 1000 metres, and these were mostly sexually mature. Those from the greater depth were remarkable in that a large proportion had only three hooks on each side instead of seven, although others were nearly or quite mature with the normal seven hooks. These examples had otherwise all the characters of *S. lyra*, except that the head was perhaps shorter and broader than usual.

These facts seem to indicate that either there are two closely allied species or varieties included under the name *S. lyra*, or that when maturity is reached, four out of the seven hooks on each side are, in some cases at least, lost. It also seems to suggest that when mature this species migrates to a much greater depth, for no fully adult specimens were taken at the surface. Grassi did most of his work at Messina, where the currents bring up to the surface animals which normally live in deep water, and this probably accounts for his finding occasional adult specimens.

With regard to variation in different localities, it appears that most of the widely distributed species differ to some extent in widely separated areas, as is mentioned above in respect to the teeth. It is interesting to note that in all cases in the present collection, where the teeth differed in number from those of the European variety, they were more numerous, so that the average number of teeth in specimens from the Indian Ocean is considerably greater than from Europe. Another character which distinguishes the Eastern Sagittas from the European as a whole is the frequency of intestinal diverticula in the neck; these are found only in one European species, but five, or more than one-third of the whole, of those from the Maldives possess them. The same fact has been noticed by Conant with regard to the American Sagittas, a large proportion of which have the diverticula.

The fact that so many species should be common to the Eastern coast of America and to the Indian Ocean, although not found between, is remarkable, but is probably explained by the absence of complete lists from the Southern Atlantic. When the latter area has been more carefully examined, it will probably be seen that this apparent discontinuous

distribution is not real. It is rather surprising, however, that a species like *S. hispida*, recorded from the Bahamas and the coast of the United States, and therefore in the path of the Gulf Stream, should not yet have been found in the North-eastern Atlantic.

In conclusion I wish to thank Mr C. Forster Cooper, B.A., for drawing the figures in the accompanying plate.

EXPLANATION OF PLATE XIII.

The corona ciliata has been represented as a dotted line, except in Fig. 7.

FIG. 1 *A*. *Sagitta robusta* nov. sp., outline. 1 *B*. The same, head and neck.

FIG. 2. *Sagitta ferox* nov. sp., head and neck.

FIG. 3 *A*. *Sagitta polyodon* nov. sp., outline. 3 *B*. The same, head and neck.

FIG. 4 *A*. *Sagitta pulchra* nov. sp., outline. 4 *B*. The same, head and neck.

FIG. 5 *A*. *Sagitta gardineri* nov. sp., outline. 5 *B*. The same, head and neck.

FIG. 6. *Sagitta septata* nov. sp., showing peculiar structure of the ovaries.

FIG. 7. *Sagitta regularis* Aida, showing thickened epidermis, corona, and ovaries.

DRAGON-FLIES.

By F. F. Laidlaw, B.A., *Demonstrator in Zoology of the Owens College, Manchester.*

Only six species are represented in the collection. One of these appears to be new. The rest are all well-known Ceylon and Indian species, or have a still wider distribution.

Sub-Fam. **Libellulinae.**

1. Zyxomma petiolatum Ramb.

Zyxomma petiolatum Kirby, *Cat. Odonata*, p. 35.

This widely distributed Oriental species is represented in the collection by three specimens (2 ♂, 1 ♀) from Hulule.

2. Pantala flavescens (Fabr.).

Pantala flavescens Kirby, *Cat. Odonata*, p. 1.

Two males, one from Hulule, and one from Mahlos. This is the most widely distributed and one of the commonest of existing dragon-flies.

3. Rhyothemis variegata (Joh.).

Rhyothemis variegata Kirby, *Cat. Odonata*, p. 5.

This is a common Ceylon and Indian species, and belongs to a genus whose members frequent especially the neighbourhood of the sea. *R. variegata* is of particular interest on account of the remarkable differences in coloration of the wings of males and females, the pattern being totally different in the two sexes.

Mr Gardiner obtained 4 ♂ and 1 ♀ from Minikoi and a single pair from Hulule. This small series however is of considerable interest, the pair from Hulule differing strikingly from the specimens from Minikoi. These latter agree closely in size and colour with specimens in the British Museum from Ceylon; the pair from Hulule are considerably smaller, and the male in particular shows differences in the wing markings.

The following measurements serve to show the differences in size between specimens from the two localities.

Average	length	of fore-wing	of males	from	Minikoi	38 mm.
"	"	"	male	"	Hulule	34 mm.
"	"	"	female	"	Minikoi	37·5 mm.
"	"	"	"	"	Hulule	30 mm.
"	"	abdomen	of female	from	Minikoi	28 mm.
"	"	"	"	"	Hulule	19 mm.

In the male from Hulule there is a dark spot covering the triangle and supra-triangular space of the fore-wing, in the Minikoi specimens this dark mark is confined to the triangle.

On the hind-wings of the former specimen there is on either side an irregular transverse dark band running from the nodus to the hind margin, in the latter this is represented only by scattered patches of colour.

The yellow on the wing of the female specimen from Minikoi is more intense and extends further than on the wing of that from Hulule.

The neuration of the two forms agrees closely.

4. TRITHEMIS (?) TRIVIALIS (Ramb.).

Trithemis trivialis Kirby, *Cat. Odonata*, p. 18.

8 ♂, 7 ♀ labelled Minikoi.
1 ♂, 1 ♀ labelled Maldives.

The length of the fore-wing in the largest male is 28·5 mm., in the smallest 26 mm. The abdomen measures 22 mm. and 19·5 mm. respectively. The average length of the male fore-wing is about 27·5 and of the abdomen about 21 mm. The females vary less in size. In them the average length of the fore-wing is 27 mm. and of the abdomen 21·5 mm., and the range of variation from the average does not exceed a millimetre.

These specimens are considerably larger than specimens in the British Museum from Ceylon, an average male specimen from the latter locality measured about 22 mm. along the fore-wing, whilst a female of the same species from Christmas Island had the fore-wing about 21·5 mm. in length.

In Mr Gardiner's series of this species the average number of costal antenodal nervules is 8, the last not being continuous. In two males and three females there is a supernumerary antenodal on the fore-wing of one side or the other, in most cases interpolated between the 6th and 7th antenodal and not continuous. The largest specimen, a male, has 8 continuous antenodal and a terminal non-continuous antenodal on both fore-wings. The smallest specimen has 8 antenodals in all on both fore-wings. The usual number of postnodals on the fore-wings is 6. In the largest male and in two other large specimens there are 7 on both sides, and in four other cases there are 6 on one side and 7 on the other, the remainder including the smallest specimen have 6 on both sides. Thus the largest specimen has the maximum number of costals on either fore-wing, viz. 16, whilst the smallest specimen, also a male, has the minimum number, 14.

The characters of the triangles, supra- and sub-triangular spaces are constant. The antenodal costals of the hind-wing number 6 6, save in one case, where there are 7 on one side.

All the females have a small area at the base of the hind-wings tinged with bright orange; this mark is almost entirely absent, only a trace of it occurring in the younger specimens. The yellow and black markings on the body become obscured in old males by a dark bluish waxy bloom.

5. ORTHETRUM SABINA (Dru.).

Orthetrum sabina Kirby, *Cat. Odonata*, p. 35.

Five specimens, 4 ♂, 1 ♀ from Minikoi.

These specimens resemble closely examples from Ceylon in the British Museum.

Sub-Fam. **Agrioninae.**

6. ENALLAGMA (?) MALDIVENSIS, sp. n.

Females with a spine at the apex of the eighth abdominal segment on its ventral side. The tenth abdominal segment of the male has no tubercle on its dorsal side.

The lower sector of the triangle of both fore- and hind-wings originates at the level of the basal post-costal cell. The pterostigma is lozenge-shaped, of a dull grey colour, lying over about half a cell; it is slightly smaller in the hind wings than in the front pair.

Lower lip divided for about a fourth part of its length from its apex. Post-ocular markings linear, hinder margin of prothorax not turned up. Abdomen moderately slender, legs small, with 5 spines on the external lateral side of the 3rd pair of tibias.

♂. Coloration for the most part dull bronze-black, variegated as follows:—

Head. Lower lip yellowish-white, labrum dull blue. The first joint of either antennae, and a line connecting them running across the pons, yellowish-white. A pale blue post-ocular line extending right across the occiput.

Prothorax. Anterior margin pale blue, there is also a pale blue spot on either side immediately over the first pair of coxae.

Thorax. Dorsal surface bronze-black with a pale blue humeral stripe on either side. Sides of thorax blue, fading into yellowish-white on the ventral surface. Legs yellowish-white with black spines and a black line running along the posterior surface of each femur.

Abdomen. Segments 1—3 brown-black above, blue at the sides, passing into yellowish-white below. Segments 4—7 similar but the blue on the sides is obscure, these segments being very slender. Segments 8, 9 blue. Segment 8 has a fine mid-dorsal bronze line which widens gradually towards the posterior end of the segment. The posterior half of the upper surface of segment 9 and the whole dorsal surface of 10 bronze. Rest of 10 blue. Appendages black.

Appendages. Upper pair conical, divaricated, larger than the lower pair, each of them with a conical tooth on its ventral surface, directed posteriorly. Lower pair very minute.

♀. Coloration of the head and thorax similar to that of the male, but the blue colour is replaced by a yellowish-brown. The colouring of the first seven segments of the abdomen is as in the male, but the blue at the sides of segments 4—7 is more evident, these segments not being so attenuated as they are in the male. Segments 9 and 10 blue; 9 with a mid-dorsal bronze spot covering its anterior half, 10 with a fine mid-dorsal bronze triangle, having its apex directed posteriorly, which occupies about the first third of the segment. Appendages black.

Length of the fore-wing about 18 mm.

Length of the abdomen ♀ about 22·5 mm.

" " " ♂ " 24 mm.

The first two joints of the antennae are short and stouter than the third, which is however as long as the first two together. The upper side of the quadrilateral of the fore-wing is about one-third as long as the lower side, on the hinder wing it is about two-thirds as long.

Five specimens (2 ♂, 3 ♀) from Mahlos and Hulule. This species differs considerably from the typical species of *Enallagma* in that the lower sector of the triangle rises at the level of the basal post-costal cell, and in the colour pattern of the abdomen. It appears to be an isolated form.

THE ACTINOGONIDIATE ECHINODERMS OF THE MALDIVE AND LACCADIVE ISLANDS.

By F. Jeffrey Bell, M.A., *Emeritus Professor and Fellow of King's College, London.*

By the kindness of Mr Stanley Gardiner I have had the opportunity of examining the Echinoderms collected by him in the Maldive and Laccadive Islands. The collection is of the ordinary coral-reef type, and consists, as did that from the Macclesfield Bank (see *Proc. Zool. Soc. London*, 1894, p. 392), very largely of young forms; these are, of course, of very great value and interest, more, I think, than any number of "new species," but they make no show in a systematic report. When a study is made of the changes that occur during post-larval growth these specimens will be seen at their full value. There are a large number of *Ophiuroids*, and some would probably, if determined, require describing as "new species"; since 1888, however, we have known of 132 (or 120) species of *Ophiuroids* from the Indo-Pacific area (see Brock, *Zeitschr. f. wiss. Zool.* xlvii. p. 538); since then I and others have helped to swell the list, but, so far as I know, no one has done anything to codify or set in order the numerous so-called species, based, many of them, on one or a few specimens, and often so described as to be quite misleading. I have not thought it my duty on this occasion to swell the list. On the other hand, just as in the Bassett Smith collection, I was able to detect the rare and interesting *Ophiopteron elegans*, so in the Stanley Gardiner collection I have found the very rare *Ophiaethiops unicolor* described by Brock in the journal just cited. As I have also found *O. elegans* in some quantity I am able to point out that Brock's statement as to the poverty of the western forms of the Indo-Pacific, as compared with the eastern, requires some modification.

Lastly, there is a point which is of far wider interest than the discovery of new species in these variable forms; again and again on working through the *Ophiuroids* I have observed that the upper surface of the disc has disappeared. I can only again urge on those who are for a time staying near a reef to investigate the problem which I raised in 1888, and which, to his regret (see *Tijds. Nederl. Dierk. Ver.* v. (1898), p. 306) was not known to Dr Sluiter till ten years later. It is clear that, if the gonads of an *Ophiuroid* be set free by the separation of the disc, and if a new disc be formed and new gonads developed, the question of germ-plasm may be considered settled.

I have endeavoured as on some previous occasions (see especially *P.Z.S.* 1887, p. 523) to avoid the treatment at inordinate length which appears to be a real joy to many naturalists;

I have given a systematic list of the species with references sufficient to make clear what is meant, and aid in any further research that it may be desirable to make; the nature of the bottom is stated, and in many cases the frequency or rarity of the species is mentioned.

CRINOIDEA.

I. Genus **Antedon.**

Immature forms—not identifiable—were dredged on 10 occasions, sometimes in considerable numbers, between 19 and 37 *f.* (fathoms), and a few were also secured by diving off the west reef of Hulule. They seem to especially frequent the inner ends of the passages, where they embouch into the lagoons; in all cases the bottom is recorded as having rubble or coral, with perhaps sand or weed.

1. *Antedon laevissima.*

Comatula laevissima Grube, *J.B. Schles. Ges.* LIII. (1875), p. 74.

Antedon laevissima, P. H. Carpenter, *Chall. Rep. Comat.* (1888), p. 197.

I still hope to be able to obtain the late Dr P. H. Carpenter's notes on Grube's 'type.'

Dredged eight times in seven atolls between 20 and 37 *f.*, usually from a hard sand or shell bottom with some weed. In one dredging, 37 *f.*, in the middle but just within the N. passage of Suvadiva, some adults and thousands of the immature forms of this species of Crinoid—and no other—were obtained.

2. *Antedon milberti.*

Comatula (Alecto) milberti, Müller, *MB. Akad. Berl.* 1846, p. 178.

Antedon milberti, P. H. Carp. *Chall. Rep. Comat.* (1888), p. 194.

Suvadiva, 43 *f.*, sand, strewn with dead oyster shells.

3. *Antedon palmata.*

Comatula (Alecto) palmata, Müller, *Physik. Abhandl. Akad. Berlin,* 1847 (1849), p. 261.

Antedon palmata, P. H. Carp. *Chall. Rep.* (1888), p. 226.

Kolumadulu, 38 *f.*, mud and weed, and Mulaku, 40 *f.*, weed, fine sand and rubble.

4. *Antedon indica.*

Comatula indica, E. A. Smith, *Ann. Mag.* XVII. (1876), p. 406; *Phil. Trans.* 168 (1879), p. 564.

Antedon indica, P. H. Carp. *Chall. Rep.* (1888), p. 225.

From the west reef of Hulule, Male Atoll, among corals.

5. *Antedon variipinna.*

Antedon variipinna, P. H. Carp. *J. Linn. Soc. Lond.* XVI. (1882), p. 506; *id. Chall. Rep.* (1888), p. 256, *ibique citata.*

S. Nilandu, 19 *f.*, at the seaward end of a passage, living corals.

II. Genus **Actinometra.**

Young forms were obtained off the coral masses of the west reef of Hulule. It is noticeable that neither this genus nor Antedon was found in the lagoon nor on the reefs of Minikoi.

6. *Actinometra typica.*

Phanogenia typica, Lovén, *Öfv. Vet. Akad. Förh.* 1866, p. 231.

Actinometra typica, P. H. Carp. *op. cit.* p. 296.

Suvadiva, 42 *f.*, hard sand.

7. *Actinometra fimbriata.*

Comatula fimbriata, Lamk. *Anim. s. Vert.* II. (1816), p. 534.

Actinometra fimbriata, P. H. Carp. *op. cit.* p. 317; Hartlaub, *Nova Acta Leop. Carol. Akad.* LVIII. (1891), p. 102.

Dr Hartlaub has already called attention to a specimen which he referred to this species, part of which was, in the terminology of Carpenter, bi-, and the other part tri-distichate. Several specimens in the present collection exhibit the same striking peculiarity; in 1894 (*P.Z.S.* p. 398) I adduced evidence against the value of the syzygy as a specific character; now doubt is thrown on the safety of the number of the distichals.

From the western reef-edge, Hulule, and dredged six times in five atolls, 24—35 *f.*, rubble or sand, mud or weed.

8. *Actinometra multiradiata.*

Asterias multiradiata, Linn. *Syst. Nat.* (1758), p. 663.

Comatula multiradiata, Lamk. *Anim. s. Vert.* II. (1816), p. 533.

Actinometra multiradiata, Duj. and Hupé, *Echinodermes* (1862), p. 210; P. H. Carp. *Chall. Rep.* (1888), p. 322.

Hulule, 15—20 *f.*, from slope of western reef, hard bottom.

9. *Actinometra sentosa.*

Actinometra sentosa, P. H. Carp. *op. cit.* p. 325.

N. Male, 25 and 27 *f.*, coral masses and coarse sand.

10. *Actinometra maculata.*

Actinometra maculata, P. H. Carp. *op. cit.* p. 307.

From the west reef of Hulule, and very commonly seen at shallow depths on lagoon reefs in all the more open atolls of the Maldives.

ASTEROIDEA.

III. Genus **Acanthaster.**

11. *Acanthaster echinites.*

See the synonyms given by Prof. Perrier in *Arch. Zool. expér.* IV. (1875), p. 361, and the observations of M. de Loriol, in *Mém. Soc. Phys. et d'hist. nat. de Genève,* XXIX. no. 4 (1885), pp. 6 *et seq.*

From the sand flat to the north-west of Hulule.

IV. Genus **Linckia.**

A number of young forms collected one night in the swabs, when at anchor in N. Male, 25 *f.*, rubble, *Polytrema* and sponges.

12. *Linckia laevigata.*

Asterias laevigata, Gmelin, *Syst. Nat.* (1788), p. 3169.

Linchia laevigata, Lütken, *Videnskab. Meddel.* 1871, p. 47.

From the boulder zone of the reef at Minikoi only.

13. *Linckia multiforis.*

Asterias multiforis, Lamk. *Anim. s. Vert.* III. (1816), p. 254.

Ophidiaster multiforis, M. Tr. *Syst. Aster.* (1842), p. 31.

Linckia multiforis, von Martens, *Arch. f. Naturg.* XXXII. (1866), p. 65.

Common on every reef of the Maldives, especially frequenting the shaded under-surfaces of stones of the boulder zone. Large numbers were attracted at Minikoi to a baited basket placed under a stone, after 24 hours no less than 37 specimens being collected.

V. Genus **Scytaster.**

14. *Scytaster variolatus.*

Asterias variolata, Retzius, *Diss. spec. Aster.* (1805), p. 19.

Scytaster variolatus, M. Tr. *Syst. Aster.* (1842), p. 34.

S. Nilandu, 25 *f.*, with corals, sponges and Alcyonarians, and Mulaku, 25, 30 and 35 *f.*, all mud and a little weed.

15. *Scytaster novae-caledoniae.*

Scytaster novae-caledoniae, Perrier, *Arch. Zool. expér.* IV. (1875), p. 426.

Found on all the sand-flats in the Maldives and Minikoi. In colour it is generally brown or blue; most forms at Minikoi were blue, while five specimens from Hulule were all brown.

VI. Genus **Ophidiaster.**

16. *Ophidiaster cylindricus.*

Asterias cylindrica, Lamk. *Anim. s. Vert.* III. (1816), p. 255.

Ophidiaster cylindricus, M. Tr. *Syst. Aster.* (1842), p. 29.

A regular denizen of the boulder zone of every reef visited in the Maldives, also at Minikoi. See Dr Mac Munn's Note on the pigment of this species, pp. 189—90, Vol. I. Part II. of this publication.

VII. Genus **Retaster.**

The genus was represented by a few immature forms from Mahlos, 23 *f.*, and Mulaku, 30 *f.*, sand and rubble.

VIII. Genus **Mithrodia.**

17. *Mithrodia clavigera.*

Asterias clavigera, Lamk. *Anim. s. Vert.* II. (1816), p. 562.

Mithrodia clavigera, Perr. *Arch. Zool. expér.* IV. (1875), p. 378.

Suvadiva, 30 *f.*, across the inner end of a passage, hard bottom.

IX. Genus **Fromia.**

18. *Fromia milleporella.*

Asterias milleporella, Lamk. *Anim. s. Vert.* II. (1816), p. 564.

Fromia milleporella, Perr. *Arch. Zool. expér.* IV. (1875), p. 437.

A single specimen found under the overhanging side of a growing coral near the edge of the east reef of Naifaro, Fadifolu.

X. Genus **Asterina.**

19. *Asterina cepheus*[1].

Asteriscus cepheus, M. Tr. *Syst. Aster.* (1842), p. 41.

Asterina cephea, Perr. *Arch. Zool. expér.* V. (1876), p. 235.

Fadifolu, 15 *f.*, from a passage covered with coral growth, and from the outer reef off Maradu, Addu. Immature forms are common on the Maldive reefs, but only the single above-mentioned adult was obtained. The young cling to the rock of the reef-flat or boulder zone, and do not seek cover in the daytime as do most species.

XI. Genus **Pentagonaster.**

Two immature forms were dredged from 35 *f.*, Kolumadulu, dead, and broken shells.

XII. Genus **Stellaster.**

Young specimens from 30 *f.*, S. Nilandu, hard sand, corals and sponges, and 40 *f.*, Mulaku, weed, sand and rubble.

20. *Stellaster incei.*

Stellaster incei, Gray, *Proc. Zool. Soc. Lond.* 1847, p. 76.

Pentagonaster (*Stellaster*) *incei*, Perr. *op. cit.* V. p. 43.

Dredged three times in different atolls, 23—30 *f.*, sand and rock.

[1] Some writers say cephea, but, as any astronomer will tell them, cepheus is a star, and was the name of a Greek king.

XIII. Genus **Astropecten.**

Immature forms from 40 *f.*, Suvadiva, broken corals and nullipores, and Halimeda, and 34 *f.*, Felidu, sand covered with weed.

21. *Astropecten polyacanthus.*

Astropecten polyacanthus, M. Tr. *Syst. Aster.* (1842), p. 69.

Dredged five times in four atolls, 19—38 *f.*, hard bottom with corals, or mud with weed and sponges (Mulaku).

22. *Astropecten indicus.*

Astropecten indicus, Döderlein, *Zool. JB. Syst.* III. (1888), p. 828.

Suvadiva, 40 *f.*, fine mud.

XIV. Genus **Luidia.**

23. *Luidia maculata.*

Luidia maculata, M. Tr. *Syst. Ast.* (1842), p. 77.

S. Nilandu, 19 *f.*, seaward end of a passage.

OPHIUROIDEA.

XV. Genus **Ophiocoma.**

Large numbers of immature specimens are obtained on breaking up decaying corals and under beach sandstone masses between tide marks. They are sometimes also found in sponges.

24. *Ophiocoma erinaceus.*

25. *Ophiocoma scolopendrina.*

In 1887, I wrote (*Scient. Trans: Roy. Dublin Soc.* III. (1887), p. 648), "It is almost certain that in a short time systematists will be agreed as to the necessity of uniting these two species of *Ophiocoma.*" In 1888 the late Dr Brock (*Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 495), said, "Es ist wohl jetzt kein Zweifel mehr, dass beide Arten vereinigt werden müssen." Fifteen years' further experience only confirms me in this view.

The form called *O. erinaceus* is characteristic of the reefs of Minikoi and all parts of the Maldives wherever there is decaying coral rock. It was dredged also with dead coral rubble off a shoal in Suvadiva, 25 *f.* The second form, *O. scolopendrina*, was only found at Minikoi, where it is numerous under stones on the reef to the east of the island.

26. *Ophiocoma valenciae.*

Ophiocoma valenciae, M. Tr. *Syst. Ast.* (1842), p. 102.

A regular species of the boulder zone in Minikoi and all parts of the Maldives.

27. *Ophiocoma brevipes.*

Ophiocoma brevipes, Peters, *Arch. f. Nat.* 1852, p. 85.

On every part of the reefs of Minikoi and the Maldives, but especially numerous under beach sandstone masses.

XVI. Genus **Ophiomastix.**

28. *Ophiomastix annulosa.*

Ophiomastix annulosa, M. Tr. *Syst. Ast.* (1842), p. 107.

Minikoi only, common in the boulder zone.

29. *Ophiomastix venosa.*

Ophiomastix venosa, Peters, *Arch. f. Naturg.* 1852, p. 83.

Common in the Maldives, at Hulule a regular form in and under coral masses on the sand-flat.

XVII. Genus **Ophionereis.**

An immature specimen from Kolumadulu, 22 f., sand and rubble.

30. *Ophionereis porrecta.*

Ophionereis porrecta, Lyman, *Proc. Boston Soc. N. H.* VII. (1860), p. 260.

Dredged three times in different atolls, 24—35 *f.*, coral, rubble or hard bottom.

XVIII. Genus **Ophiothrix.**

Immature forms—often very numerous—in 11 dredgings, 22—46 f., usually sand with some rubble, but in the deepest fine, hard mud.

31. *Ophiothrix aspidota.*

Ophiothrix aspidota, M. Tr. *Syst. Ast.* (1842), p. 115.

Suvadiva, 20 *f.*, across the inner end of a passage, hard bottom.

32. *Ophiothrix nereidina.*

Ophiura nereidina, Lamk. *Anim. S. Vert.* II. (1816), p. 544.

Ophiothrix nereidina, M. Tr. *Syst. Ast.* (1842), p. 115.

Minikoi and Maldives, under corals of reef-flat.

XIX. Genus **Ophiopteron.**

33. *Ophiopteron elegans.*

Ophiopteron elegans, Ludwig, *Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 459.

Dredged five times in 3 atolls, 22—35 f., in every case near passages, hard bottom, perhaps rubble and weed.

XX. Genus **Ophioaethiops.**

34. *Ophioaethiops unicolor.*

Ophioaethiops, Brock, *Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 524.

This is the most interesting of Mr Gardiner's finds, as, with the exception of the three specimens found at Amboina by Brock, the species is unknown. I had little doubt as to the identity of the creature, but to make sure I submitted it to Prof. Ehlers of Göttingen,

who compared it with the originals. As Brock remarked that *Ophioaethiops* was closely allied to Dr Marktanner-Turneretscher's *Ophiolophus* I was glad of the opportunity afforded me by Dr von Marenzeller of comparing the two. I confess I was struck by the differences between them.

In a hole of a coral mass from the reef of Naifaro, Fadifolu.

XXI. Genus **Astrophyton.**

35. *Astrophyton clavatum.*

Astrophyton clavatum, Lyman, *Proc. Boston Soc. N. H.* VIII. (1861), p. 85.

Mahlos, 24 f., dead and living corals, and Suvadiva, 38 *f.*, coarse shell and coral fragments.

ECHINOIDEA.

XXII. Genus **Cidaris.**

36. *Cidaris metularia.*

Cidarites metularia, Lamk. *Anim. S. Vert.* III. (1816), p. 56.

Cidaris metularia, A. Ag. *Rev. Ech.* (1872), p. 98.

Found constantly on every part of all the reefs visited, wedged in between the branches of growing corals. Dredged five times with corals, 20—25 *f.*

XXIII. Genus **Diadema.**

37. *Diadema saxatile.*

Echinus saxatilis, Linn. *Syst. Nat.* (1758), p. 664.

Diadema setosum, auct. plurim.

Diadema saxatile, Lovén, *Bih. Sven. Vet. Akad. Hdlgr.* 13, IV., no. 5 (1887), p. 135.

Found on every reef under stones or in hollows of the boulder zone, or between growing corals.

XXIV. Genus **Echinothrix.**

38. *Echinothrix diadema.*

Echinus diadema, Linn. *Syst. Nat.* ed. X. (1858), p. 664.

Echinothrix calamaris, A. Ag. *Rev. Ech.* (1872), p. 119.

Echinothrix diadema, Lovén, *Bih. Sven. Vet. Akad. Hdlgr.* 13, IV. no. 5 (1887), p. 137.

Both this and the next species were common in Minikoi and in the Maldives in the same position as *Diadema saxatile.*

39. *Echinothrix desori.*

Astropyga desori, Ag. *Ann. Sci. nat.* VI. (1846), p. 345.

Echinothrix desori, A. Ag. *Rev. Ech.* (1872), p. 120.

XXV. Genus **Astropyga.**

Immature forms, N. Male, 25 *f.*, coral masses, Polytrema, etc., and Mulaku, 30 *f.*, green and dead weed, also from Minikoi lagoon, 6 *f.*

XXVI. Genus **Asthenosoma.**

40. *Asthenosoma urens.*

Cyanosoma urens, Sarasins, *Zool. Anzeig.* IX. (1886), p. 80.

Asthenosoma urens, iid. *Ergeb. Forschungen auf Ceylon*, I. (1888), p. 86.

A large number of specimens, Mulaku, 27 *f.*, mud and sponges, also Haddumati, 40 *f.*, mud and weed, and Suvadiva, 43 *f.*, soft mud.

XXVII. Genus **Temnopleurus.**

Immature forms in 5 dredgings, 22—25 *f.*, sand, weed and generally rubble.

41. *Temnopleurus toreumaticus.*

Cidaris toreumatica, Leske, *Addit. ad hist.* p. 155.

Temnopleurus toreumaticus, Agass. *in Valentin's Anat. du genre Echinus* (1841), p. viii; Bell, *P.Z.S.* 1880, p. 428.

Mulaku, 28 *f.*, and Haddumati, 40 *f.*, mud and weed.

XXVIII. Genus **Salmacis.**

42. *Salmacis bicolor.*

Salmacis bicolor, Agass. *op. cit.* p. viii.; Al. Ag. *Rev. Ech.* (1872), p. 156.

Suvadiva. 30 *f.*, hard sand (?), and Haddumati, 32 and 40 *f.*, dead coral masses, mud and weed. The Suvadiva specimen had associated with it a similarly coloured Gastropod, which was resting in an especial clearing among its spines.

XXIX. Genus **Tripneustes.**

43. *Tripneustes angulosa.*

Cidaris angulosa, Leske, *Addit.* (1788), p. 92.

Tripneustes angulosa, Bell, *P.Z.S.* (1879), p. 657.

Occasionally found at Minikoi and the Maldives on the sand-flats, not uncommonly cast up on the lagoon beaches.

XXX. Genus **Echinometra.**

44. *Echinometra lucunter.*

Echinus lucunter, Linn. *Syst. Nat.* ed. x. (1758), p. 665.

Echinometra lucunter, De Blainv. *Actin.* (1834), p. 225; Lovén, *Bih. Sv. Vet. Akad. Hdlgr.* 13, IV. no. 5 (1887), p. 153.

Wedged into hollows in the extreme seaward edges of all reefs, almost where the rollers break. The animal varies rather in colour, the lighter forms occurring further out.

XXXI. Genus **Fibularia.**

A large number of immature specimens from a velu or lagoon of one of the smaller rim atolls (faro) of N. Male, 5 *f.*, coarse sand.

45. *Fibularia volva.*

Fibularia volva, Ag. *Ann. Sci. Nat.* VII. (1847), p. 142; Al. Ag. *Rev. Ech.* (1872), p. 130.

Mahlos, 24 *f.*, living and dead coral.

XXXII. Genus **Echinoneus.**

46. *Echinoneus cyclostomus.*

Echinoneus cyclostomus, Leske, *Addit.* (1778), p. 173; Al. Ag. *Rev. Ech.* (1872), p. 117.

From sand under stones or coral masses on the sand-flats at Minikoi and throughout the Maldives. A large number of young specimens were dredged in the lagoons of Minikoi and Hulule, 6—8 *f.*, these appearing to be their nurseries. The young shells were never found alive on any surface reef, but they are a regular constituent of sandy beaches.

XXXIII. Genus **Laganum.**

Immature forms dredged 6 times, 30—36 *f.*, hard bottom with rubble, corals, sponges and weed.

47. *Laganum depressum.*

Laganum depressum, Ag. *Mon. Scutel.* (1841), p. 110.

Dredged 9 times in 6 atolls, 18—38 *f.*, rubble bottom with sand, or mud and perhaps weed.

XXXIV. Genus **Clypeaster.**

An immature specimen from a passage into S. Nilandu, 25 *f.*, corals and sponges.

XXXV. Genus **Brissopsis.**

Immature forms only, from Mulaku, 30 *f.*, sand and weed.

XXXVI. Genus **Brissus.**

A few immature specimens from Hulule.

XXXVII. Genus **Lovenia.**

48. *Lovenia elongata.*

Spatangus elongatus, Gray, in Eyre, *Discov. Central Austral.* I. (1845), p. 436; Al. Ag. *Rev. Ech.* I. (1872), p. 139.

Lovenia elongata, Gray, *Ann. and Mag. N.H.* VII. (1851), p. 131.

Only from the sand-flat to the north of Hulule, under corals.

XXXVIII. Genus **Maretia.**

49. *Maretia alta.*

Maretia alta, A. Ag. (1863), see *Rev. Ech.* 1872, p. 139.

Felidu, 34 *f.*, sand covered with weed.

50. *Maretia planulata.*

Spatangus planulatus, Lamk. *An. s. Vert.* III. (1816), p. 31.

Small forms found occasionally at low tide level on lagoon flats everywhere. Dredged 7 times in Kolumadulu and Felidu, 20—35 *f.*, rubble or shells and sand, also Haddumati, 40 *f.*, weed and mud.

ORTHOPTERA.

By Malcolm Burr, F.Z.S., F.E.S., F.L.S.

The collection includes twenty-four species, of which one adult, a *Liphoplus*, cannot be identified with any known form. Almost all the others are cosmopolitan or widely distributed Oriental species, probably all occurring also in India or Ceylon. A few field notes have been added by Mr Stanley Gardiner.

FORFICULARIA.

1. *Anisolabis annulipes* Luc. Minikoi, 1 ♂.

BLATTODEA.

2. *Periplaneta americana* L. Minikoi. Common throughout the Maldives, infesting the larger boats, but seldom found on shore.

3. *Leucophaea surinamensis* L. Minikoi, I ♂, 1 ♀.

4. *Phyllodromia vitrea* Br. Minikoi, 2; Hulule, 1; Mahlosmadulu, 1. Rare in the Maldives, only being found in the northern atolls of the group.

5. *Epilampra* sp. Minikoi, 3 larvae, obtained at the lighthouse.

6. *Panesthia* sp. Mahlosmadulu, 1 larva.

MANTODEA.

7. *Hierodula simulacrum* Serv. Minikoi.

This form is fairly common near the village and in the dense jungle to the south of the main island of Minikoi, principally affecting the shrubby *Hibiscus* trees. Occasionally it is caught against the lantern of the lighthouse. The larvae, while rare elsewhere, are common round the freshwater, coir-making pools near the village. The species is not found in any part of the Maldives.

ACRIDIODEA.

Fam. **Truxalidae.**

8. *Epacromia tamulus* Fabr. Minikoi, Hulule, Goidu, Mahlosmadulu and Miladumadulu; a large number of specimens.

This species is abundant and widely distributed throughout the Oriental region. It is the commonest grasshopper in the Maldives and Laccadives, any number being caught in open, dry spots by means of the sweep-net.

Fam. **Pyrgomorphidae.**

9. *Atractomorpha gerstaeckeri* Bol. Minikoi, 1 ♂.

10. *Atractomorpha similis* Bol. Hulule, 1 ♂.

11. *Atractomorpha crenulata* Fabr. Minikoi.

Very common in the above island, frequenting the paths in the densest jungle. Much more numerous towards sunset.

Fam. **Acridiidae.**

12. *Oxya intricata* Stal., var. *tibiis posticis ferrugineis.* A large number of specimens from Minikoi, Mahlosmadulu, Miladumadulu, Goidu and Hulule.

This form is only found in the northern part of the Maldive Group, and does not extend to Suvadiva and Addu. It is in no island so abundant as at Minikoi. The species frequents open spaces, especially the dry grain lands of Miladumadulu atoll.

13. *Acridium septemfasciatum* Serv. Minikoi, 1 ♂, 1 ♀, not found in the Maldives.

Fam. **Tettigidae.**

14. *Hedotettix gracilis* Haan. Minikoi, 1 ♂.

LOCUSTODEA.

Fam. **Phaneropteridae.**

15. *Phaneroptera indica* Br. A number of specimens from Minikoi, Mahlosmadulu and Hulule. The commonest locust in the Maldives, found throughout the whole group from Miladumadulu to Addu.

All the specimens appear to be referable to the above species, but are somewhat smaller than the dimensions given by Brunner.

Fam. **Conocephalidae.**

16. *Conocephalus breviceps* Redt. Minikoi, 1 ♀; Mahlosmadulu, 2 ♂, 1 ♀.

17. *Conocephalus* sp. Hulule, 1 ♀ larva.

18. *Xiphidium maculatum* Le Gou. A number of specimens from Minikoi and the Maldives.

A widely distributed Oriental species. It is very common in Minikoi, but, although seen in nearly every atoll of the Maldives, rare everywhere.

GRYLLODEA.

Fam. **Myrmecophelidae.**

19. *Liphoplus* n. sp. Minikoi, 1 ♀.

This appears to be a new species, but I refrain from describing it as the collection contains but a single female, not in perfect condition. It differs from *Liphoplus fasciatus* Br., in its paler colour and larger size; from *L. novarae* in its larger size and black-bordered elytrae; and from *L. guerinianus* in its paler colour.

20. *Ectatoderus longicaudus* Sauss. Minikoi, 2 ♂, 6 ♀ and 4 larvae. Common in the roots of the grass near the lighthouse.

I am not quite positive as to the correct identification of this species, but the genus is little known, and the species are not very clearly defined. The specimens from Minikoi approach nearer to this than any other described form.

Fam. **Trigonididae.**

21. *Trigonidium cicindeloides* Serv. Minikoi, 4 ♂, 3 ♀ and 3 larvae.

This species is common on the shores of the Mediterranean, and occurs also in Ceylon and Burmah.

22. *Homoexiphus histrio* Sauss. Minikoi, 2 ♀.

Fam. **Gryllidae.**

23. *Landreva picta* Sauss. Hulule, 1 ♀.

I refer the single female with some hesitation to this species.

24. *Gryllus mitratus* Burm. Minikoi, 1 ♀; Mahlosmadulu, 1 ♀; and Hulule, 1 ♂. A common Oriental species.

MARINE CRUSTACEANS.

III. THE XANTHIDAE AND SOME OTHER CRABS.

By L. A. Borradaile, M.A., *Lecturer in Natural Sciences at Selwyn College, Cambridge.*

(With Text-figures 41—60.)

The instalment of the Marine Crustaceans of the Expedition described in this paper includes, besides the Xanthidae, two new genera, possibly allied to them, and a couple of small families—the Atelecyclidae and the Hapalocarcinidae—which are taken here for reasons of convenience. Some remarks on the natural history of the crabs will be found under the headings of the families, genera, etc. to which they belong.

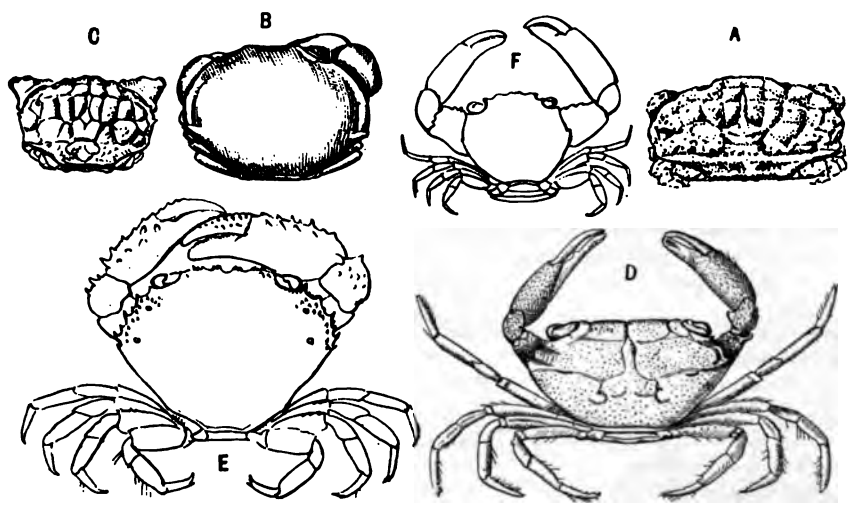

Fig. 41. Types of the Xanthid Crabs. *A. Actaea fossulata*, resembling water-worn coral pebbles and found in the lower parts of a coral stock or other situations into which pebbles could be washed. *B. Carpilius exsculptus*, adapted for passively withstanding surf and currents. *C. Euxanthus exsculptus* var. *rugosus*, found amongst stones, etc. on the reef. *D. Chlorodius barbatus*. *E. Domoecia hispida*, a coral crab. *F. Trapezia ferruginea*, also a coral crab. The drawings are not made to scale. *B* is a large crab, *C* and *F* of moderate size, and the others small.

Family **Xanthidae.**

Of all the families of crabs the Xanthidae are the most numerous in genera and species, and the most varied in form, though this preeminence is seen chiefly in the Tropics, and there best in the littoral belt, where they are to be found in every possible position.

Morphologically, the Xanthids are characterised, among the other round-fronted crabs (Cyclometopa), by the absence of a rostrum, the sloping or transverse first antennae and short second antennae, the sharp fore edge to the mouth, and the legs of the last pair not adapted for swimming, nor the branchial regions swollen. Bionomically they are harder to characterise, but, speaking broadly, we may say that they are not sand crabs, nor swimming crabs, nor land crabs, but essentially crabs of the reef surface and the coral stocks, though some of them may be found in other positions. Their division into subfamilies and genera depends on such characters as the shape of the orbits and antennae, and the relationships of these to one another, the ridges on the palate (endostome) which mark out the channels by which water leaves the gill-chamber, and the shape of the body[1]. The species are separated by details such as the shape of the front and the hands, the sculpture and areolation of the carapace, and the presence or absence of spines on the limbs or the sides of the body.

The body of a typical Xanthid—a *Xantho*, for instance (Fig. 50), or an *Actaea* (Figs. 41 *A*, 53, 54), or *Carpilius* (Fig. 41 *B*), is of a transversely oval shape, heavy and compact, with a hard cuticle and short legs, which can be folded up close under the body[2]. The chelae are usually large and powerful, and the habits sluggish. Such crabs live almost anywhere on the reef, sometimes showing a preference for some particular kind of shelter, such as holes or cracks in the rocks, but more often, I think, adapting themselves to any that can be found. Specimens are thus often taken in coral stocks, though the crabs cannot be said to be characteristically coral crabs, being equally, if not more often, found under stones, which afford the most favourite hiding-place of all; some of the larger species are restricted to the reef, but many of the smaller ones are also to be found in the lagoon wherever coral

[1] In the following key the sub-families of the Xanthidae are defined by means of these features:

I. Endostome ridges wanting. Shape of the body transversely oval or rounded.

A. Flagellum of antenna not shut out of orbital gap.

1. Second joint of antennal stalk cylindrical, reaching the front but not entering the orbital gap.
Xanthinae.

2. Second joint of antennal stalk as in Xanthinae but entering the orbital gap.
Carpilinae.

B. Flagellum of antenna shut out of orbital gap by part of the second joint of the stalk.
Etisinae.

II. Endostome ridges present. Shape of the body often square or squarish.

A. Front less than half, and fronto-orbital edge (front and orbits together) not more than two-thirds the greatest breadth of the carapace. Front usually makes an arch with the anterolateral edge. Flagellum of antenna usually not shut out of orbital gap.

1. Second joint of antennal stalk cylindrical, and may or may not reach the front, with which it is not broadly in contact. Endostome ridges vary in shape and size.
Menippinae.

2. Second joint of antennal stalk somewhat irregular in shape and broadly in contact with the front. Endostome ridges strong, and project on the fore edge of the mouth.
Oziinae.

B. Front at least half, and fronto-orbital edge more than two-thirds the greatest breadth of the carapace. Front makes an angle with the anterolateral edge. Flagellum of antenna always shut out of orbital gap.

1. Endostome ridges strong, and project on the fore edge of the mouth.
Eriphiinae.

2. Endostome ridges moderate, and make no projection on the fore edge of the mouth.
Trapeziinae.

The genera will be found ranged under these sub-families below.

[2] The figure (41 c) of *Euxanthus exsculptus* gives an excellent example of the way in which the limbs are often folded up so as to form with the body a compact mass. Fig. 47 shows how the legs are sometimes specially shaped for folding into a small compass.

grows. The massive, compact form of body and the strong cuticle are, no doubt, adaptations to a life spent in positions where they are surrounded with hard, stony objects, and exposed at times to surf and strong currents, and at others to enemies which they are unable to escape by swimming like the Portunidae.

From this typical body-form there are, of course, deviations in various directions, of which a few only can be mentioned here. Such genera as *Chlorodius* (Fig. 41 *D*) and *Pseudozius* (Fig. 45) are flatter and lighter built, with longer legs, though the cuticle is still strong, and they are more often to be found in situations like the interstices of coral stocks, where they must maintain their position by the use of their limbs, rather than by their weight or by wedging themselves fast, like the heavier genera. Yet even these[1] are far from being true coral crabs, restricted to the living parts of the stock, like *Melia* (Fig. 49), *Domecia* (Fig. 41 *E*), or the Trapeziinae (Figs. 41 *F*, 58), on which some remarks will be found below[2]. Another very characteristic *habitus* is that of *Pilumnus* (Figs. 46—48), slightly built, very hairy, and often with squarish, rather than oval, bodies, falling very steeply in front.

As to the meaning of the numerous, and often very beautiful, features by which the Xanthids are distinguished in detail, it is as yet impossible, in most cases, to say anything. Why, for instance, are the species of *Actaea* bejewelled with the most beautiful pearly granules (Figs. 53, 54)? And why do these granules become sharp thorns in some species (Fig. 56), and flatten themselves into leaflets in others (Fig. 55)? Why should the back of *Euxanthus* (Fig. 41 *C*) be rough and uneven, or that of *Carpilius* (Fig. 41 *B*) glassy smooth? Why is *Liomera* barrel-shaped (Fig. 52) and *Pseudozius* often as flat as a board (Figs. 43, 44)? Before these questions can be answered, much more must be known about the habits of the crabs. We may, however, indicate some directions in which it will be well to look for the answer. The texture of the back and legs, and their nakedness or hairiness, will perhaps be found to depend on the necessity of friction with the surrounding objects when the animal wedges itself firmly into its hiding-place, or of presenting a smooth surface to waves and currents, so that they may pass over the animal without sweeping it away; or again to the need of disguise, either by a covering of fine silt, held by hairs or bristles (often a very effectual device) or by adherent organisms which will not grow on a smooth surface, or even [*Actaea cavipes* and *fossulata* (Fig. 41 *A*)] by a likeness to water-worn pebbles of coral. The shape of the hands may be adapted to the food, or to defence against some special enemy, or—in correspondence with that of the front—to breathing among foreign particles of various grades of coarseness[3], or in some cases seems to be a sexual character. The remarkable hoof-like ends to the fingers (Fig. 57 *C*), which turn up again and again in different genera[3], may serve to give their owner a foothold among the rough coral branches, or may gather food in some special way, like the tufted, spoon-like fingers of the prawn *Atya*. The shape of the front depends on the way in which the antennae are used, and on the need of keeping open a way for the breathing stream, a function which it shares with the chelipeds[4]. And lastly the shape of the end-joints of the walking legs, which shows a

[1] Except, probably, *P. coralliophilus* and *P. triunguiculatus* (p. 241 ff.).

[2] pp. 249, 268.

[3] Garstang, *Q. J. M. S.* XL. p. 211.

[4] This phenomenon of the occurrence of the same feature in groups which cannot be related to one another is not uncommon among Decapods, and is worthy of more attention than it has yet received. Another instance of it, mentioned below (p. 242), is the pulley arrangement at the end of the walking legs. Of course the closure of the orbital gap has happened over and over again in various groups of Crabs, and the loss of the mandibular palp and the epipodites among Prawns is a similar case.

very great diversity, will be found, I believe, to be connected with the nature of the ground on which the animal's life is passed, whether it live among stones or in sandy places or in coral stocks, and to its habits, whether it crouch with folded limbs under shelter or hold fast with its legs.

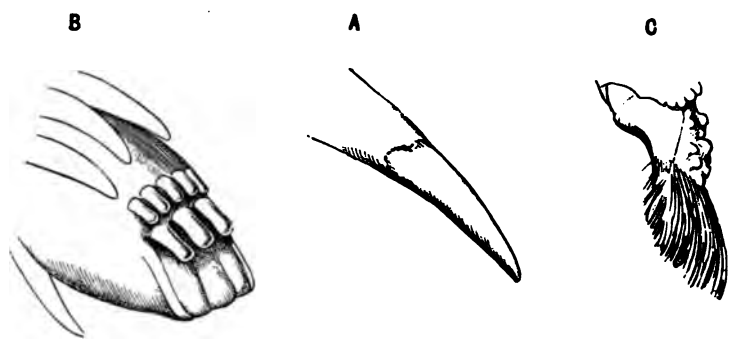

FIG. 42. Ends of the walking legs of Xanthid Crabs. *A*. Tip of the end-joint in *Carpilius convexus* (Fig. 41 *A*). *B*. Same part in *Trapezia ferruginea* (Fig. 41 *F*). *C*. Whole end-joint in *Actaea speciosa*. The drawings are not made to scale, *A* being much less enlarged than *B* or *C*.

A number of examples of this feature may be found in the illustrations scattered through the present paper, but in the accompanying figure (Fig. 42) three of the most unlike of them are shown enlarged. *Carpilius convexus* is a heavy-bodied, spindle-shanked crab, too big and clumsy to climb among the branches of coral stocks, which leads a sluggish and uneventful life among objects on the bottom, and has even been found enclosed as in a cage by the growth of coral[1]. Its legs (*A*) accordingly end in a very simple claw. *Trapezia ferruginea* is a typical crab of the living coral, and we may suppose that the remarkable ending of its legs (*B*) is in some way connected with this fact. But what can be the meaning of the curious brush of hairs at the end of the first walking leg of *Actaea speciosa* (*C*), and why this structure is not found on the other legs, cannot as yet be even guessed. Some remarks on the different ways in which the last joint may be hinged on to that before it will be found below on p. 242.

According to Henderson [*Tr. Linn. Soc. Zool.* (2) v. p. 332] the colour markings of shore Decapoda are generally protective in their nature, but this is certainly not always the case, as, for instance, in *Trapezia* and *Carpilodes*.

In another respect, besides those of structure and habits, the Xanthids offer a contrast to the swimming crabs, described in the last number of this publication, which, next to them, are the most conspicuous family of crabs in the Tropics. They are, with some striking exceptions, not very variable, and are not varietal, save in a few cases. In the Trapeziinae, however, varieties appear, and the genus *Pilumnus* shows a remarkable plasticity of constitution, which leads to the formation of numerous local species and will be alluded to again below[2].

[1] Coutière, *Bull. Mus. hist. nat.*, 1898, 5, p. 238.

[2] p. 244.

Subfamily **Menippinae.**

Genus *Pseudozius* Dana, 1851.

1. *Pseudozius dispar* Dana, 1852.

Pseudozius dispar, Calman, *Tr. Linn. Soc.* (2) VIII. p. 14 (1900)[1].

The granular field on the larger hand of the male of this species grows relatively smaller with age.

Taken on the reef in Male, Goifurfehendu and Fadifolu Atolls, and in Funadu Velu, Miladumadulu Atoll.

2. *Pseudozius caystrus* (Ad. and Wh.), 1848. Alcock, III. p. 181.

This very common species, which is recorded by Alcock from the Laccadives, almost certainly occurs at Minikoi, though unfortunately no specimens of it have reached England[2].

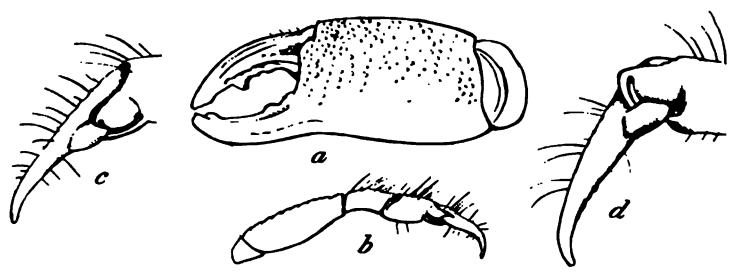

FIG. 43. Limbs of *Pseudozius coralliophilus*; *a*. outside of greater hand, *b*. walking leg, *c*, *d*. end of the same enlarged.

3. *Pseudozius coralliophilus*, n. sp. (Fig. 43).

Diagnosis: "A *Pseudozius* with the carapace finely granular, bearing a few scattered hairs, the regions faintly marked out; the front sloping gradually downwards, cleft into two low, rounded lobes, the furrow between the front and the orbit ending on a small lobe; the antero-lateral edge with three very low humps, from the last of which a fine ridge runs inwards on the back; the chelipeds unequal, finely granular, their fingers widely gaping, especially on the large hand, furrowed and subcylindrical, with a few isolated blunt teeth, the arm and wrist (meropodite and carpopodite of the cheliped) without spines, the fore edge of the arm finely toothed; and the walking legs fairly stout, with a long end-claw."

Length: 3 mm. Breadth: 4 mm. Colour in spirit: cream, with pale brown, cream-tipped fingers.

A single male specimen was taken from a block of the brain-coral *Leptoria tenuis* growing in the lagoon at Minikoi. It was sheltering at the bottom of one of the holes in the coral made by another little crab—*Cryptochirus coralliodytes*[3]. Whether the first owner of the hole had died, or left willingly, or had been ousted by the *Pseudozius* there was nothing to show, nor can we tell as yet whether the latter lives always in *Cryptochirus*-holes or had merely retreated into one in this case as the water drained off the surface of the coral. In another of these holes there was found a female *Pseudozius*, sheltering in the same way, and it was

[1] Where synonyms will be found. For the principle on which references are given in this paper see p. 192 of Part II. of the present publication.

[2] See footnote to p. 191 of Part II. of this publication.

[3] See below, p. 271.

natural to suppose at first that this was the female of the crab whose male we have just described. Further examination, however, showed differences between the two so great that they must belong to different species. The second specimen is described below under the name of *P. triunguiculatus.*

I am much obliged to Mr Edwin Wilson, F.E.S., for calling my attention to a very interesting structure which he discovered on the legs of this crab (Fig. 43 *b*—*d*). As usual, the last joint (dactylopodite, end-joint) is held in a deep notch at the end of the one before it (propodite). But in the present case it bears on the hinder side a flange, and on the flange a knob, which works in a groove on the propodite. At the inner end of this groove is a small pit, into which the knob slips when the joint is fully flexed, so that the end-joint is held firm in this position, thus providing the crab with a hook, by which, no doubt, it keeps its position on the coral. *P. triunguiculatus* has a less perfect form of the same apparatus (Fig. 44 *c*). In it, the flange on the last joint works against a special process of the one before

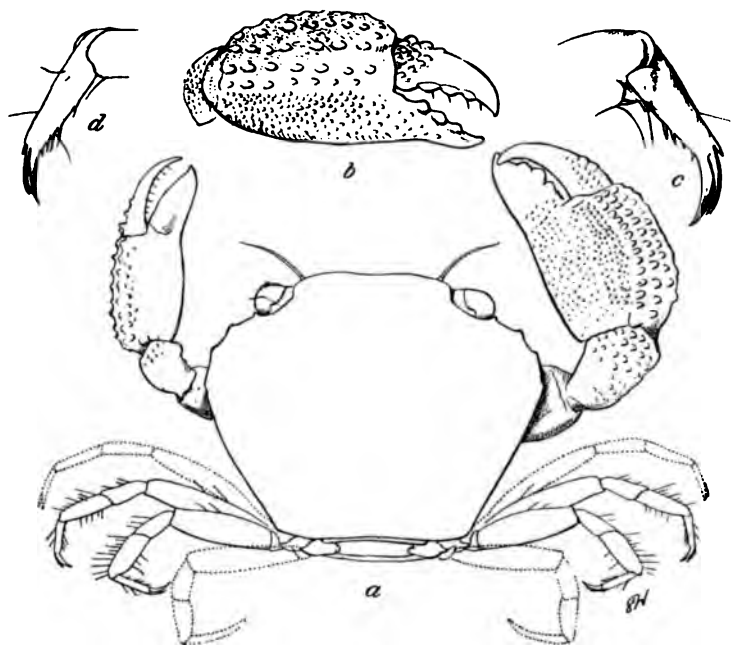

FIG. 44. *Pseudozius triunguiculatus*, symbiotic with a coral; *a*. whole animal, *b*. outside of greater hand, *c*. hinder side of end of walking leg, *d*. fore side of the same.

it, but this process has only a smooth surface and no groove. A small spine under the propodite seems placed in this position to prevent the end-joint from being unduly flexed, and no doubt the other spines give a foothold to the animal. On the whole, these structures, as well as the general appearance of the body and limbs, give the impression that the crabs are indeed symbiotic with the coral, living always on its surface, but take refuge in the *Cryptochirus* holes at times only.

Interestingly enough, the same structure, in its simpler form of a flange on the end-joint working along a smooth path on the joint before it, turns up again in the coral crabs of the Trapeziinae and in *Domecia*, though not in *Melia*, which crooks the whole leg and not the last joints only, and is also present in *Chlorodopsis* (Fig. 57 *c*) and *Phymodius*, which, without

being true coral crabs, are often found in coral stocks, and in the *Actaeas* of the *flosculata*-group, of whose habits as yet nothing is known, since they have only been taken with the dredge. *Actuea speciosa* (Fig. 42 *C*) is an example of a species in which the flange is not found. The object of the apparatus is, no doubt, to enable the end-joint to be moved more evenly and accurately and held fast in any position; and it is only an elaboration of structures found in most crabs, which have usually a small facet on the hinder side of the last joint for the end of the propodite. Its absence is, nevertheless, particularly interesting in the case of *Eriphia*, which is allied to *Domecia*, and of *Pseudozius* other than the two species mentioned above. A single glance at the orbits of these latter species is enough to show that they have no place among the Trapeziinae, Eriphiinae, or Etisinae, so that the formation of the legs in question must have arisen, like so many other characters of the crabs, independently in two or more cases[1]. It is probably an adaptation to clambering.

4. *Pseudozius triunguiculatus*, n. sp. (Fig. 44).

Diagnosis: "A *Pseudozius* with the carapace flat, smooth (microscopically roughened) and hairless, the regions not marked out; the front sloping slightly downwards, standing well forward beyond the eyes, with a wide shallow bight instead of the usual notch in the middle, no side lobes, and a shallow median furrow; the anterolateral edge with three low, blunt teeth, the hindermost of which is hardly distinguishable; the chelipeds, large, unequal, covered with granules of some size, which are largest on the upper part of the outside of the hand, no spines on the arm or wrist, the fingers flattened, not gaping, sharply pointed at the tips, in the large hand the fingers set, on their opposed edges, with a row each of conical teeth, in the small hand these edges blade-like, making up a remarkable pair of shears, which are no doubt adapted to some peculiarity in the habits; and the walking legs rather slender, each bearing on its last joint a set of three slender, brown end-claws, of which two are somewhat smaller than the third."

Length: 3 mm. Breadth: 4 mm. Colour in spirit: pale brown, the walking legs white, the back covered with small dark-brown spots, the fingers white.

One female specimen taken on *Leptoria tenuis* in Minikoi lagoon.

Subgenus *Platyozius*, n.

A specimen dredged in Suvadiva cannot be referred to any known species, and is also difficult to place in a genus. It differs from *Pseudozius*, as hitherto defined, in more than one point, but none of these is of importance enough to warrant the setting up of a new genus, and it is therefore taken here as the type of a new subgenus *Platyozius*. Other groups of species akin to *Pseudozius* will probably have to be reduced to this rank before long.

Platyozius differs from *Pseudozius* s. str. in the following points: (1) Relatively greater fronto-orbital breadth. (2) Absence of small outer lobes from the front. (3) Equality of the chelipeds. (4) Slenderness of the legs. (5) A flatter and shallower body. (6) Less marked endostome ridges.

5. *Pseudozius* (*Platyozius*) *laevis*, n. sp. (Fig. 45).

Diagnosis: "A *Platyozius* with the carapace smooth, hairless, without regions; the front broad, bent slightly downward, almost straight, with a broad shallow bight in the middle and

[1] See above, footnote to p. 239.

notches separating it from the orbits, but no outer lobes; the anterolateral edges short, with two big blunt triangular teeth behind the orbital angle, and a small notch, rather than a projecting tooth, at the junction with the posterolateral edge; the hinder edge slightly hollowed; the chelipeds equal, smooth, without spines but with a blunt tooth at the inner angle of the

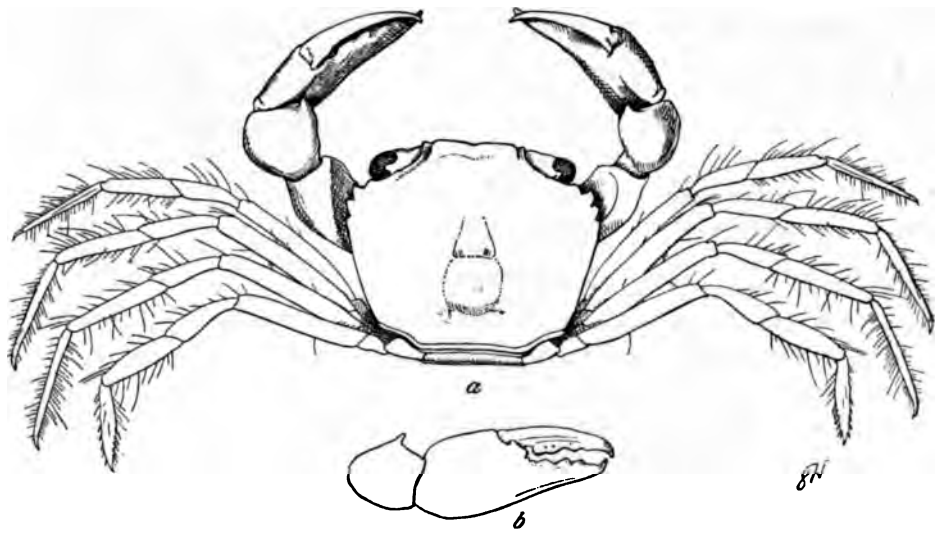

FIG. 45. *Pseudozius laevis*; *a.* whole animal, *b.* outside of hand.

wrist, the fingers compressed, grooved, not gaping, each with a row of triangular teeth interlocking with those of the other; and the walking legs long, slender, sparsely hairy, and without spines, except on the dactylopodite of the last leg, which is rather broad, while those of the other walking legs are very long and narrow."

Length: 5 mm. Breadth: 6 mm. Colour in spirit: white.

One male specimen dredged in 20 fathoms in Suvadiva Atoll.

Genus *Pilumnus*, Leach, 1815.

As a general rule the species of crabs are not local in distribution, but are spread over wide areas and are probably correlated with habitative[1] rather than geographical differences in environment. There are, of course, exceptions to this rule, as for instance the land and freshwater crabs of the genera *Sesarma* and *Potamon*. *Pilumnus* is another of these exceptions, as may be seen at once on looking down a list of the known species, when it will be evident that many of them have been only recorded from one locality. This impression is strengthened on reading the remarks of various authors in recording a species from a new locality. In many cases the identification is doubtful, or the description does not tally with that of the original specimens. The present collection affords an excellent example of this, not one of the 11 species being represented by specimens which exactly obey former diagnoses. Under the circumstances I shall describe as new species the forms which do not agree closely with specific descriptions already published, and rank as subspecies[2] those which in-

[1] For the meaning of this word, see p. 195 of Part II. of this publication.

[2] See footnote to p. 195 of Part II. of this publication.

fringe such descriptions in small points only. The phenomenon of local variation in *Pilumnus* deserves, and would repay, careful investigation, especially with regard to the existence of intermediates, their number relative to those of the described forms, and their distribution, whether they be found in intermediate localities or no. In short, information is needed as to whether the subspecies of *Pilumnus* be "discontinuous," like true varieties, or no.

The members of the genus live under stones, in coral blocks, etc.

6. *Pilumnus vespertilio* (Fabr.) 1793. Alcock, III.[1] p. 192.

The fur of the Maldive specimens is not dark, as in the type, but of a golden-yellow colour, like that of Alcock's Karachi and Tavoy race. At the same time the usual smooth patch is to be found near the base of the finger of the large hand. Perhaps these characters are distinctive of local races or subspecies of *P. vespertilio.*

The species, which is sluggish in its habits, lives under stones, etc., and was taken on the reef at Hulule, Male Atoll, and in Funadu Velu, Miladumadulu.

7. *Pilumnus andersoni* de Man, 1887. subsp.[2] See Alcock, III. p. 194.

The Maldive specimens differ from the race defined by Alcock in the following points: (1) There are no granules on the carapace, which is everywhere smooth and finely pitted. (2) The spines on the fore edge of the meropodites of the walking legs are vestigial, and there is no spine at the end of the joint. (3) The arrangement of the spines on the fore edge of the arm does not agree with that described by de Man. Alcock does not mention these spines, but, as he cites de Man's paper, it is presumable that all his specimens presented the same arrangement as the type. In the Maldive example there is a row of strong, blunt teeth, growing smaller from without inwards. In de Man's specimens there were two, large, arched, sharp spines at the outer end, with a small spine at the base of the distal of the two. The more proximal was larger than the distal one, and behind it were four or five acute granules.

Dredged in 5—39 fathoms in Minikoi, South Nilandu, and Haddumati Atolls.

8. *Pilumnus hirsutus* Stimps, 1858. subsp. See Alcock, III. p. 197.

The Maldive specimens differ from those on which Alcock's description was founded in the following points: (1) A small subhepatic tooth is present. (2) The gaps on the orbital edge are fairly distinct.

According to Haswell (*Cat. Austral. Crust.* p. 69), the meropodites of the walking legs of this species should bear three or four spines. Alcock does not mention these spines, and they are wanting in the Maldive specimens, in which the fore edge of the meropodite is roughened by a row of low, blunt teeth. Alcock is doubtful about the identity of the species he is describing as *P. hirsutus*, and it seems likely that the three forms[3] are distinct.

A single specimen from South Nilandu, which bears a *Sacculina*, differs from the others in the following points: (1) The antennal flagella are long and hairy. (2) The large hand is rather less "full." (3) The body is rather flatter. (4) The legs are a little longer.

[1] *Journ. As. Soc. Beng.* LXVII. ii. pp. 67—233 (1898). For the principle on which references are given in this paper see Vol. I. Part II. p. 192 of the present publication.

[2] See footnote to p. 195 of Part II. of this publication.

[3] I am using the word "form" in its broadest sense to include species, subspecies, and varieties. In this sense it is a useful counterpart of "group," used to include all divisions of the animal kingdom from genera upwards. For definition of "variety" and "subspecies" see the article on Varieties in Part II. of this publication.

It is impossible to say whether any or all of these features be due to the presence of the parasite.

The figure of a specimen referred to this species in the *P.Z.S.* for 1900 [pl. XLII., fig. 9] was drawn with the hair on the body and in consequence the side-teeth and frontal notch have not been shown by the artist.

Dredged in 22—45 fathoms in Haddumati, Felidu, Addu, Mulaku, North Male, South Nilandu, Suvadiva, and Kolumadulu Atolls.

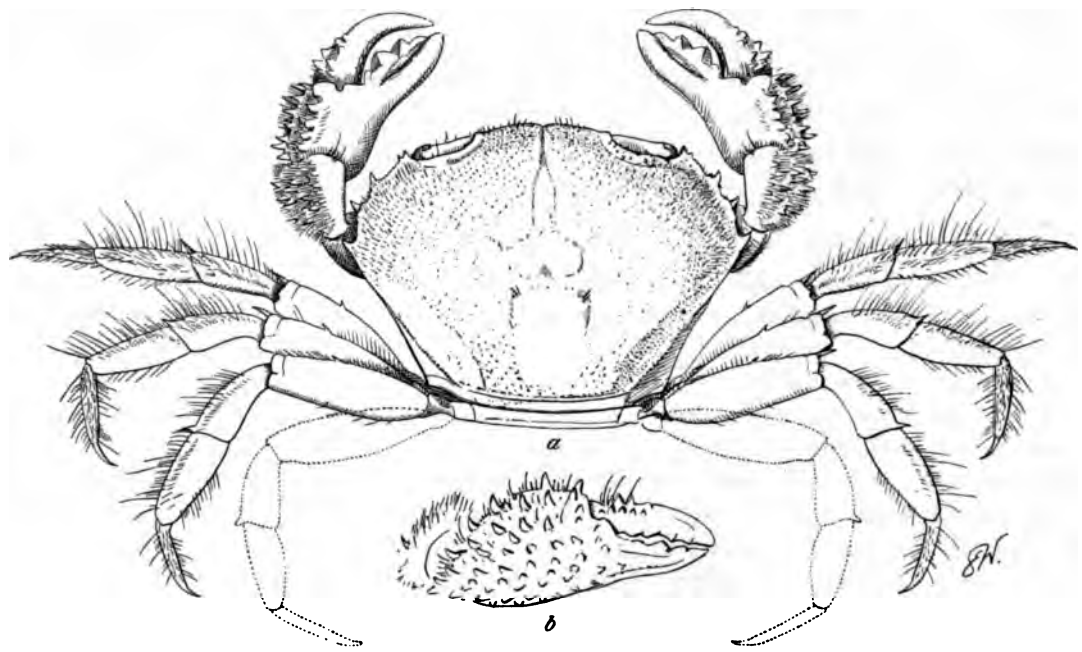

FIG. 46. *Pilumnus rotundus*; *a*. whole animal, *b*. outside of hand.

9. *Pilumnus rotundus*, n. sp. (Fig. 46).

Diagnosis: "A *Pilumnus* with the carapace very convex, subglobular, covered with short hairs, the regions faintly marked; the lobes of the front only moderately prominent, with faintly granular edge; the lower rim of the orbit denticulate, the upper rim granular, with two distinct but shallow notches; the anterolateral edge bearing four spiniform teeth, of which the first is the orbital angle, the teeth being short and set wide apart and having smaller teeth at their bases; the chelipeds rather unequal, covered outside with stout thorns, which are arranged in somewhat irregular rows and are largest on the upper side, the fingers bent at an angle with the hand, the moveable finger bearing a strong ridge above; and the walking legs moderately long, covered with long hairs, and with a thorn on the upper edge of the meropodite and one at the end of both the meropodite and the carpopodite."

Length: 8 mm. Breadth: 12 mm. Colour in spirit: yellowish-white, with white fingers.

Dredged in 35 fathoms in Kolumadulu Atoll.

10. *Pilumnus dorsipes* Stimps, 1858. Alcock, III. p. 197.

The specimens agree very closely with Alcock's definition, but I am quite unable to detect

any granulation of the carapace, which, when laid bare, is absolutely smooth, save for the stumps of the hairs. The larger hand is very stout and the fingers short.

The species was taken in South Nilandu, Haddumati, North Male, Mulaku, Suvadiva, Felidu, Kolumadulu, and Fadifolu Atolls, in 12—70 fathoms of water.

11. *Pilumnus maldivensis*, n. sp. (Fig. 47).

Diagnosis: "A *Pilumnus* with the carapace convex both fore and aft and from side to side, smooth, pubescent and hairy, the regions faintly marked; the middle lobes of the front prominent, the outer lobes very small; the lower rim of the orbit finely toothed, the upper rim smooth, with traces of two notches; the antero-lateral edge short, with three spiniform teeth and a spine on the orbital angle; the chelipeds unequal, granular and hairy outside, a small bare patch at the base of the fingers and along the lower edge of the greater hand, fingers moderately long, smooth; and the walking legs of moderate length and stoutness, hairy and pubescent, and without thorns on the meropodites."

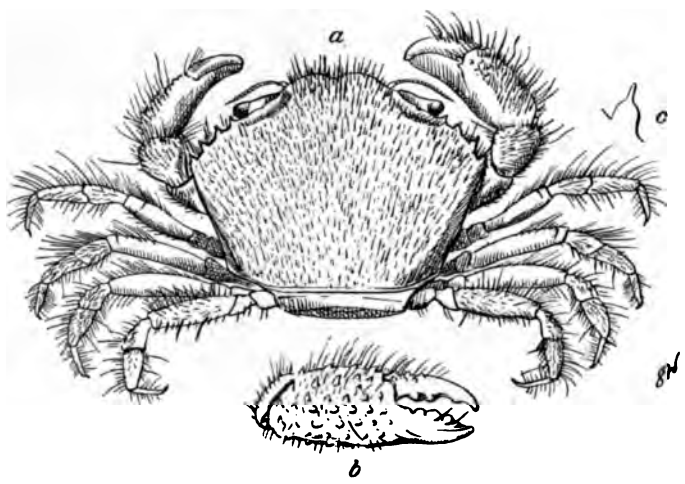

FIG. 47. *Pilumnus maldivensis*; *a*. whole animal, *b*. outside of hand, *c*. one of the teeth of the anterolateral edge.

Length: 4 mm. Breadth: 5 mm. (Largest specimen.) Colour in spirit: yellowish-white, fingers white.

This species seems to be akin to *P. caerulescens* A. M.-Edw. 1873, which is included in Major Alcock's list of Indian Crabs, but the colour and the spiniform orbital angle serve to distinguish it. It was dredged in Suvadiva, North Male, Miladumadulu, and South Nilandu Atolls, in 25—43 fathoms.

12. *Pilumnus rotumanus* Borradaile, 1900. ? subsp.

Pilumnus rotumanus Borradaile, *Proc. Zool. Soc.* 1900, p. 581, pl. XLI. fig. 6 (1900).

A single female of this crab was taken on the shore at Hulule, Male Atoll. It differs from the type specimen in two points: (1) The moveable finger, which in *P. rotumanus* has a slightly uneven cutting-edge, has in the Maldive example a row of well-marked teeth. (2) The carapace of the Maldive specimen is narrower relatively to its breadth.

Both specimens are females, but it is possible that these differences may be due to age, since the Rotuman individual is much larger than that from Hulule (length 15 mm. as against 8 mm.). Or, again, a series from each locality might show that the features in question are not characteristic.

13. *Pilumnus elegans* de Man, 1887. subsp.

See *Pilumnus elegans* de Man, *Arch. Naturges.* 53 I. p. 310, pl. XII. fig. 3 (1887).

The specimens agree with de Man's description in all points but the two following:

(1) The fore edge of the meropodites of all the walking legs bears three spines besides that at the end of the joint. In de Man's race there is only one, and that is wanting from the last leg. (2) The red colour mentioned by de Man is wholly wanting, though of course this may be due to the state of preservation.

Taken in South Nilandu Atoll, in 19—25 fathoms.

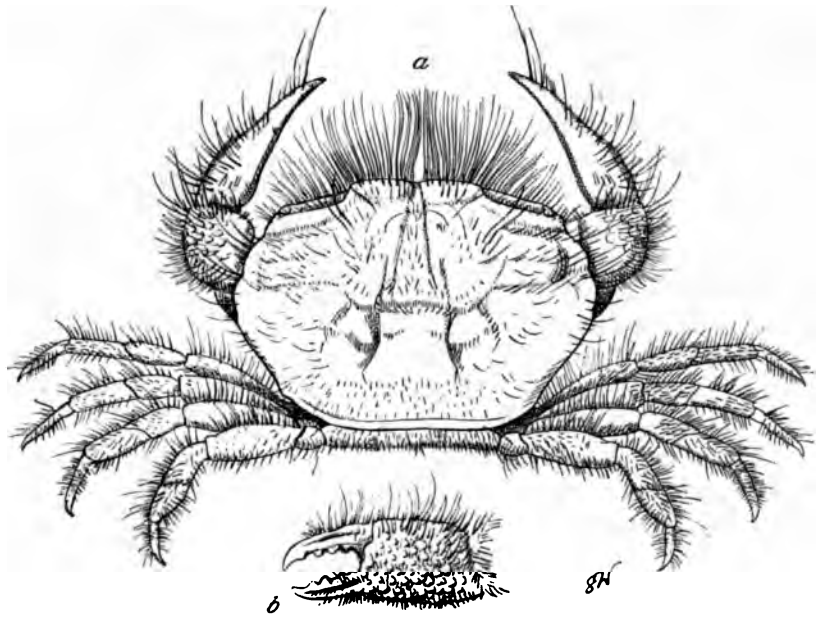

FIG. 48. *Pilumnus alcocki*; *a*. whole animal, *b*. outside of hand.

14. *Pilumnus alcocki*, n. sp. (Fig. 48).

Diagnosis: "A *Pilumnus* with the carapace of moderate breadth only, covered rather sparsely with long hairs but without pubescence, the regions well marked; the front almost straight, slightly arched, not deeply notched in the middle, bearing a fringe of very long hairs; the anterolateral edge raised into three low mounds, the hindermost of which is very inconspicuous; the outer orbital notch shallow, the inner wanting, the lower orbital rim granular, the orbital angle not at all prominent; the chelipeds subequal, granular and covered with long hairs, the fingers gaping, somewhat furrowed and toothed; and the walking legs short, stout, hairy and pubescent, and without thorns on the meropodites."

Length: 4·8 mm. Breadth: 6·2 mm. Colour in spirit: white.

Dredged in 20 fathoms in Suvadiva Atoll.

I have called this species after Major A. Alcock, F.R.S., to whose excellent work on the Indian Crabs it has so often been necessary to refer in the present paper.

Genus *Actumnus* Dana, 1851.

15. *Actumnus globosus* (Dana), 1852.

Pilumnus globosus, Dana, *U.S. Expl. Expd. Crust.* I. p. 236, pl. XII. fig. 10 (1852).

By the shape of its body this species seems to belong to *Actumnus*, rather than to

Pilumnus, though, in any case, with *A. obesus* Dana, 1852, and *A. elegans* de Man, 1887, it holds an intermediate position.

Taken on the reef at Minikoi.

16. *Actumnus setifer* (de Haan), 1835. Alcock, III. p. 202.

The carapace is very sparsely granular in the larger specimens.

Dredged in 23—30 fathoms in Mahlos and South Nilandu Atolls.

17. *Actumnus tomentosus* Dana, 1852. Alcock, III. p. 202.

Dredged in 25 fathoms in South Nilandu Atoll.

Genus *Melia* Latr., 1825.

I have followed Ortmann in placing this genus provisionally in the Menippinae chiefly because the orbital gap forbids its being included in the Trapeziinae, to which its body-shape, coral haunting habits, and coloration seem at first to show a relationship. For the rest, the shape of the body may be reached without much difficulty from that of *Pilumnus*, and none

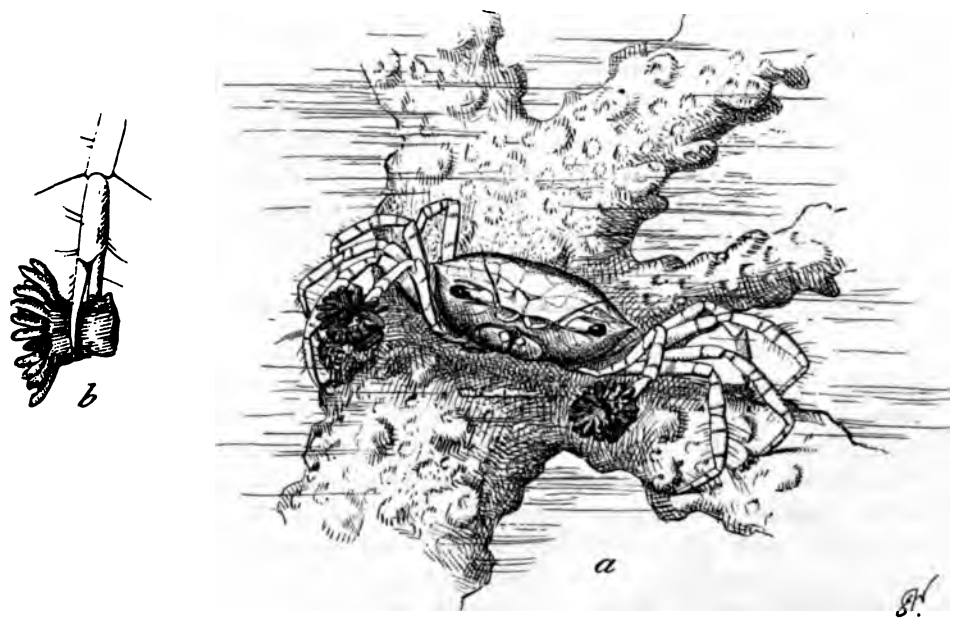

FIG. 49. *Melia tessellata*, bearing in its claws two sea anemones. The colour of this crab in life is very beautiful Its translucent legs are ringed, as in the figure, with dark purple, and lines of the same colour mark out the body into polygonal fields which are coloured pale pink or brown and lemon yellow. The anemones when alive are olive-green, and the coral pink or green. The whole figure is considerably enlarged, and *b*, which shows the "hand" holding an anemone, is very much so.

of the other characters offers any great obstacle to our classifying it with the present subfamily. It has obviously undergone considerable modifications in structure in connection with its peculiar and interesting habits.

18. *Melia tessellata* (Latr.) (Fig. 49.)

Melia tessellata, Borradaile, *Proc. Zool. Soc.* 1900, p. 580.

This crab, which lives, like *Trapezia*, among the living branches of coral stocks, holding on by its long slender legs, has for some time[1] been known to be in the habit of carrying in each chela a small sea anemone. The object of this habit is not known, but it is certainly a voluntary act on the part of the crab, for the actinian is not attached, but held between the fingers of the *Melia*, and, if it be taken away, will be again seized. Usually there is an anemone in each hand, but sometimes one or both hands are empty. The actinians, which are grasped firmly round the middle below the tentacles, may be useful, by means of their stinging-cells, either for defence or to "fish" for food with, or perhaps for both purposes. The chelipeds are slender and feeble—ill-suited for defence, but at the same time mobile and well adapted to wield the anemones they carry, and, if the crab be threatened, it will stretch out its arms towards the aggressor, as though it would ward him off with the disagreeable obstacles it thus presents to his attack. Certainly the fingers cannot be used to take food unless the anemone be first dropped, but, on the other hand, the tentacles of the latter are directed outwards, away from the mouth of the crab. The third maxillipeds are mobile, with the proximal joints rather slender and the last three stout, and are fringed with long hairs. Possibly they are used to catch small organisms for food in much the same way as those of the China Crabs (Porcellanidae), which part with their chelipeds so readily when they are attacked, since they do not use them for taking food.

In any case we seem to have here an interesting example of the use of an implement by an animal which, however intelligent, has at least a very differently organised nervous system from the Vertebrata. It should be noted that the case is different from that of a spider crab, which sticks pieces of seaweed on its back and enjoys passively the concealment gotten thereby. For the *Melia* carries the anemone in its cheliped—the chief grasping organ of the animal, corresponding to the hand of a primate or the trunk of an elephant—and, whatever its use, it cannot be a means of passive concealment, to which its size is wholly inadequate[2].

Melia tessellata is not recorded from the Indian region by Alcock, who finds the genus represented there by two quite distinct new species (*M. caestifer* and *M. pugil*). It would be interesting to know the precise distribution, geographical and habitative, of these three species. The "hairs" mentioned by Alcock as found on the fingers of his new species may possibly be the remains of actinians, rotten from bad preservation, and in that case it would be needful to determine whether each species of crab has its own species of anemone. Of course we must also know whether the latter be full grown or only young individuals. The species was taken on the reef in Male, Addu, Minikoi and Goifurfehendu Atoll.

Subfamily **Xanthinae.**

Genus *Cymo* de Haan, 1833.

The members of this genus live under stones, in coral blocks, etc.

[1] The fact was noted in 1880 by Richter (Möbius' *Meeresfauna Mauritius*), but since then its interest, and indeed its very existence, have been generally overlooked.

[2] The ant *Oecophylla smaragdina* uses its own larvae (which have glands for making a cocoon) as spinning implements to fasten together the edges of the leaves which form its home, holding them, the while, in its jaws. There is also said to be a wasp which uses a stone to beat down the earth over its burrow.

19. *Cymo andreossyi* (And.) 1826, var. *melanodactylus* (de Haan) 1833. Alcock, III. p. 174.

Taken on the shore in Minikoi and Goifurfehendu Atolls, and dredged from 12 fathoms in Fadifolu Atoll.

20. *Cymo quadrilobatus*, Miers, 1884. Alcock, III. p. 175. This species is probably identical with *C. tuberculatus* Ortmann (*Zool. Jahrb.* VII. Syst., p. 443).

Taken on the shore in Male, Goifurfehendu and Fadifolu Atolls.

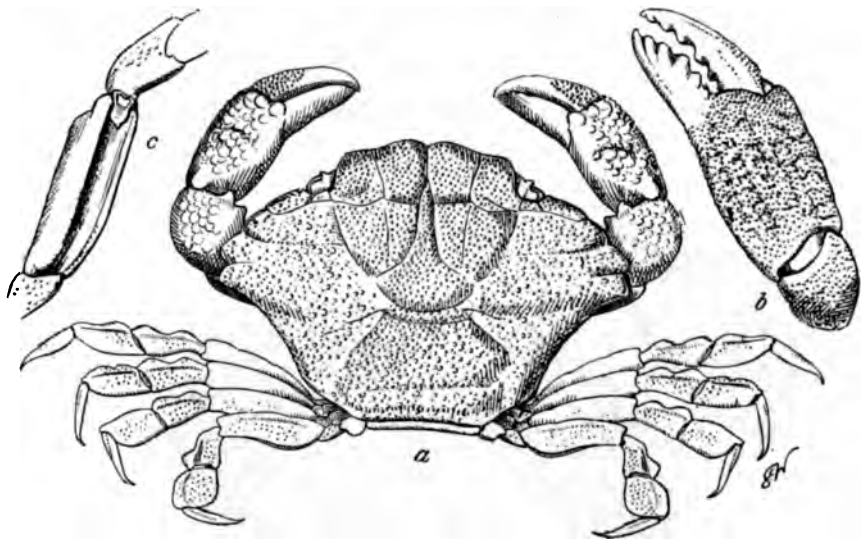

FIG. 50. *Xantho frontalis*; *a*. whole animal, *b*. outside of hand, *c*. underside of meropodite of walking leg, to show the groove into which the last three joints can be folded.

Genus *Xantho* Leach, 1815.

21. *Xantho frontalis*, n. sp. (Fig. 50).

Diagnosis: "A *Xantho* with the whole body finely and evenly granulated, the regions marked out by fine sharp lines; the front prominent, its outline like that of a cupid's bow; the anterolateral edge divided into four lobes, of which the first two are low and rounded and the last two prominent and conical; the chelipeds subequal, their outer surface rough and uneven, the hands with four indistinct longitudinal ridges, the fingers furrowed and bearing interlocking teeth, the upper side of the hand with an irregular-rounded lobe, the inside of the wrist with a conical tooth; and the walking legs short, with long end-joints, two knobs on the upper side of the carpopodite, and a hollow under the meropodite into which the outer joints can be folded."

Length: 5 mm. Breadth: 8 mm. Colour in spirit: white with pale-brown fingers.

Genus *Xanthias* Rathbun, 1897.

22. *Xanthias lamarcki* (H. M. Edw.), 1834. Alcock, III. p. 157.

Taken on the shore in Male, Goifurfehendu, Miladumadulu, Fadifolu, S. Mahlos, and Minikoi Atolls.

23. *Xanthias notatus* (Dana), 1852. Alcock, III. p. 158.

Taken on the reef and in the lagoon at Minikoi.

Genus *Leptodius*, A. M.-Edw., 1863.

The numbers of this genus may be taken under stones and in coral stocks.

24. *Leptodius nudipes* (Dana), 1852. Alcock, III. p. 121.

Taken on the shore in Male, Goifurfehendu and Minikoi Atolls; in the latter locality from a coral mass on the outer reef.

25. *Leptodius sanguineus* (H. M.-Edw.), 1834. Alcock, III. p. 119.

Taken on the shore in Goifurfehendu Atoll.

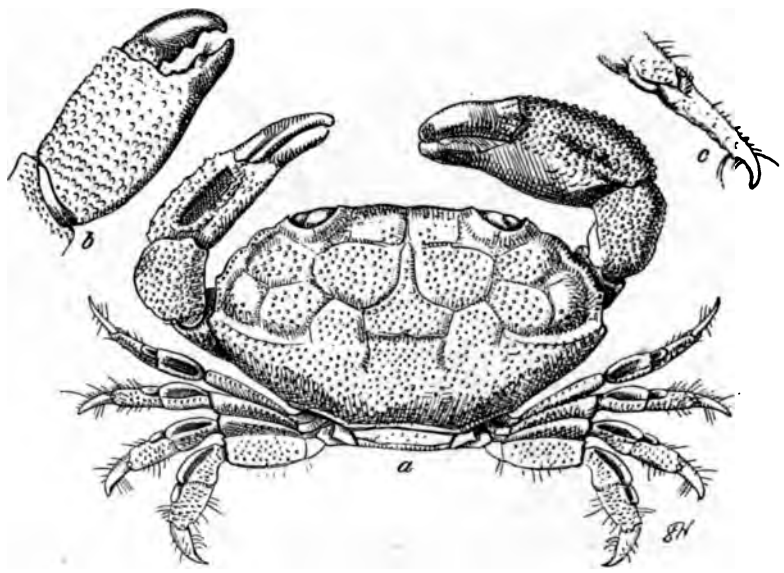

FIG. 51. *Leptodius cristatus*; *a*. whole animal, *b*. outside of hand, *c*. end of walking leg.

26. *Leptodius* (*Xanthodius*) *cristatus*, n. sp. (Fig. 51).

Diagnosis: "A *Xanthodius* with the carapace flat behind, falling steeply in front, somewhat sparsely granular all over, the granules being smaller and closer set in the hinder part, and naked, the forepart of the carapace divided up by wide, smooth grooves; the front bent strongly downwards, with an almost straight, thickened, granular edge and a rather shallow notch in the middle; the notches in the orbital rim indistinct; four low side-teeth with thickened, granular edges; the hind edge of the carapace slightly hollowed; a feeble ridge on the endostome reaching the fore edge of the mouth; the basal joint of the antenna short; the chelipeds unequal, granular all over except on the facet against the body, the hands with a crest and a smooth furrow above, the fingers deeply hoofed at the tip, a little granular at the base, furrowed on the smaller hand only, with a few blunt teeth on the larger hand; and the walking legs finely granular, their last two joints hairy; the carpopodite and propodite with a crest and a broad smooth groove above."

Length: 5 mm. Breadth: 7 mm. Colour in spirit: mottled purple and orange-brown, fingers dark-brown with paler tips.

Four female specimens were found under stones on the inner part of the reef-flat at Minikoi.

Genus *Lioxantho* Alc., 1898.

27. *Lioxantho asperatus* Alc., 1898. Alcock, III. p. 92.

The specimens agree exactly with Alcock's definition, except in not having hair on the dactylopodites.

Taken on the shore at Hulule, Male Atoll.

28. *Lioxantho tumidus*, Alc., 1898. Alcock, III. p. 91.

Taken on the shore in Male and Goifurfehendu Atolls.

29. *Lioxantho punctatus* (H. M. Edw.), 1834. Alcock, III. p. 91.

Taken on the shore at Hulule, Male Atoll.

Genus *Liomera* Dana, 1851.

30. *Liomera cinctimana* (White), 1847. Alcock, III. p. 88.

Taken on the shore at Goidu, Goifurfehendu Atoll.

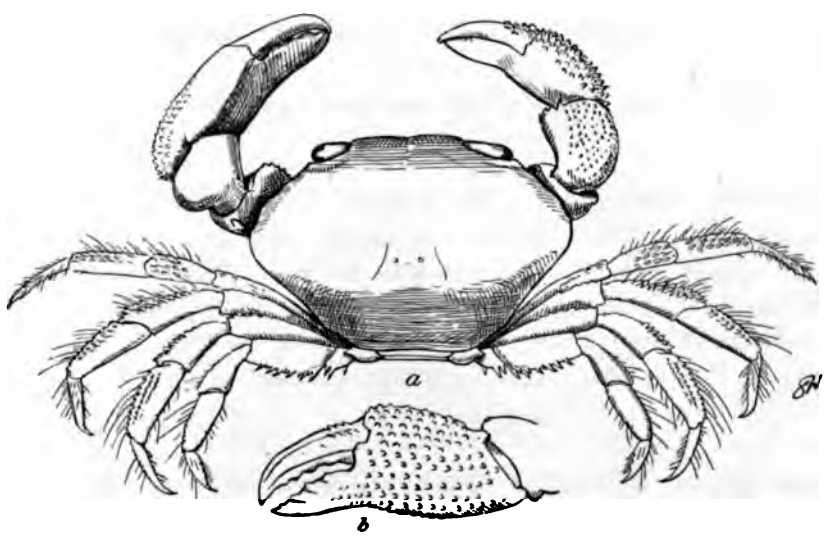

FIG. 52. *Liomera spinipes*; *a*. whole animal, *b*. outside of hand.

31. *Liomera spinipes*, n. sp. (Fig. 52).

Diagnosis: "A *Liomera* with the carapace smooth and polished, without a trace of regions, rather more than half as long as broad; the front divided into two well-marked rounded lobes of simple outline; the anterolateral edge sharp, almost crest-like in its hinder half, with traces of the last two lobes only, not marked off by a tubercle from the posterolateral edge; the orbital rim without notches; the antennal flagellum rather longer than the breadth of the orbit; the fore edge

of the third maxilliped almost straight; the chelipeds stout; the arm short and broad, with a large tooth near the end of the upper edge and the lower edge roughened; the outside of the wrist roughened in parts; the outside of the hand covered with small, sharp thorns, and some of the same thorns on the base of the moveable finger; the fingers compressed, toothed on their opposite edges, and furrowed outside; and the walking legs having the upper edge of the meropodites much compressed and finely toothed, but not crested; the lower edge of the last meropodite with long thorns, those of the other meropodites with much smaller thorns, and the carpopodites and propodites of all the legs rather sparsely hairy, with broad upper sides covered with prickles."

Length: 5 mm. Breadth: 8 mm. Colour in spirit: white.

Dredged in 30 fathoms in Mulaku Atoll.

Genus *Actaea* de Haan, 1833.

32. *Actaea tomentosa* (H. M.-Edw.), 1834. Alcock, III. p. 140.

Taken on the reef in Male, Goifurfehendu, Addu, and Minikoi Atolls.

33. *Actaea affinis* (Dana), 1852.

Actaea affinis, Borradaile, *Proc. Zool. Soc.*, 1900, p. 583.

Taken on the reef in Male, Goifurfehendu, Fadifolu, and Minikoi Atolls.

34. *Actaea rufopunctata* (H. M.-Edw.), 1834. Alcock, III. p. 142.

One very small female dredged in N. Male was without the fine felt between the lobules of the back.

Taken on the shore in Goifurfehendu Atoll, and dredged in Minikoi, North Male, and Miladumadulu Atolls.

35. *Actaea speciosa* (Dana), 1852. Alcock, III. p. 143. (Fig. 42 *C.*)

The first walking leg of this crab bears an organ which seems not to have been noticed hitherto. A brush of stiff yellow bristles surrounds and hides the end-claw on the last joint of the limb. What can be the use of this structure it is hard to see, but so definite and constant an organ must correspond to some feature in the habits of the crab.

Taken on the reef in Male, Goifurfehendu, and Fadifolu Atolls.

36. *Actaea ruppelli* (Krauss), 1843. Alcock, III. p. 144.

The specimens are not so hairy as Alcock's definition indicates. A. Milne-Edwards says that the species is "légèrement poilue." Probably the amount of hair depends greatly on the state of preservation of the specimens, in this as in other Xanthids.

Taken on the reef in Goifurfehendu Atoll.

37. *Actaea lata*, n. sp. (Fig. 53).

Diagnosis: "An *Actaea* with the carapace broad (length : breadth = about 7 : 10) and strongly lobulated all over, though the lobules are not very convex, the grooves between the lobules smooth and lined with fine dark pile, the lobules covered with pearly granules, which are smaller on the hinder lobules than on those before them, long golden-brown hairs and

shorter black bristles arising among the granules, the front bent strongly downwards, not much arched or very strongly notched in the middle line; the anterolateral edge with four low lobes, the first being confluent with the orbital angle; the orbit with two notches in its upper rim and one in the lower; the under side of the body furred, and grooves running from between the lobes of the edge over the finely granular pterygostome; the posterolateral edge not marked by a row of granules; the chelipeds subequal, the wrist and hand lobulated above, the hands swollen, rounded and covered with granules outside and inside, the fingers short, much arched, not compressed or hollowed at the tip, with a few blunt teeth on the opposed edges and some granules at the base of the moveable one, which is furrowed, though not to the tip; and the walking legs covered with granules, hairs and bristles like those of the carapace and with a furrow on the hinder side of the carpopodite."

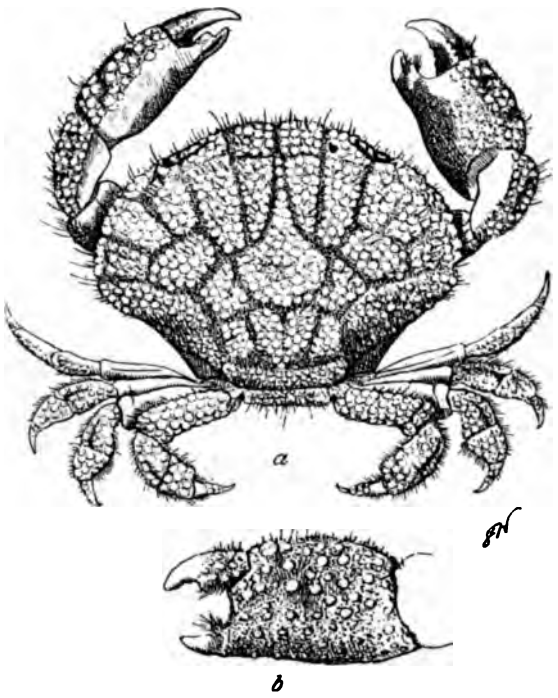

FIG. 53. *Actaea lata*; *a*. whole animal, *b*. outside of hand.

Length: 7 mm. Breadth: 10 mm. Colour in spirit: white with red spots; the fingers black with white tips, the black spreading over a great part of the inner and outer sides of the palm.

The species is allied to *A. hirsutissima* (Rüppell), 1830, and *A. kraussi* Keller, 1861, but may be distinguished from both by the shape of the hands.

Dredged in 15 fathoms in Fadifolu Atoll.

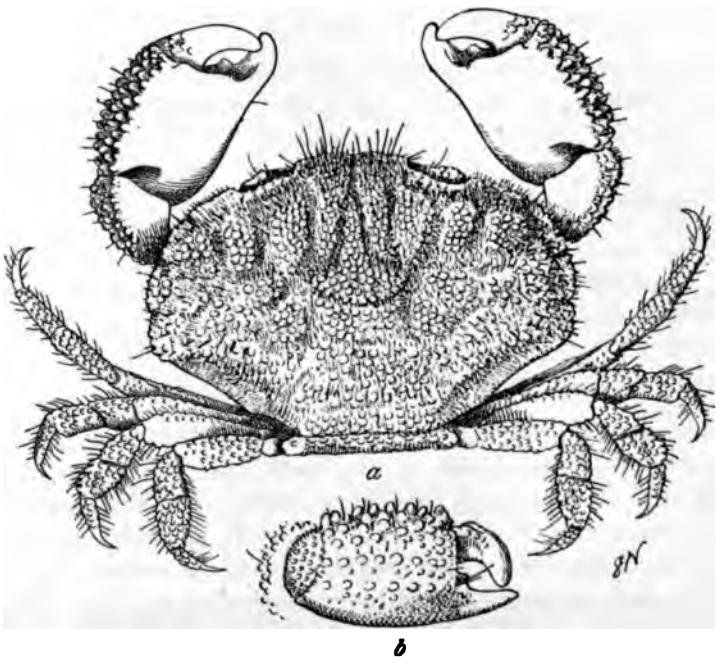

FIG. 54. *Actaea variolosa*; *a*. whole animal, *b*. outside of hand. The animal is drawn rather broader than it actually is.

38. *Actaea variolosa*, n. sp. (Fig. 54).

Diagnosis: "An *Actaea* whose length is about three-quarters of its breadth; the carapace egg-shaped, its areas numerous but separated by shallow grooves on the fore-part, wanting behind, the whole surface, except the bottom of the grooves in the fore-part, covered with rounded granules, which are largest in the branchial region and are interspersed with stout, golden-brown bristles; the front bent strongly downwards, prominent, fairly deeply notched in the middle; four indistinct side-lobes; the chelipeds equal, granular; the hands rather large, somewhat swollen, nearly square; the fingers very short, rounded, smooth save for a few small granules on the base of the moveable one, each with but one tooth, which is very blunt and lies quite at the base where it is almost hidden by tufts of strong hairs; and the outer surface of all the walking legs covered with granules like those of the cheliped but with no dimples."

Length: 6 mm. Breadth: 8 mm. Colour in spirit: white, bases of fingers black.

The species is allied to *A. obesa* A. M.-Edw., 1865, but differs in the shape of the hands.

Taken on the shore in Male Atoll.

39. ? *Actaea pulchella* A. M.-Edw., 1865. Alcock, III. p. 140.

The specimen which I have with some doubt assigned to this species has a very distinct coloration of mottled white and orange-yellow. As in Milne-Edwards's figure (*Nouv. Arch. Mus. Hist. Nat.* I., Pl. XVII., fig. 5), it is only the first of the side lobes of the carapace that can be described as indistinct, though both Milne-Edwards and Alcock apply this term to all of them. If Milne-Edwards's figure be not correctly drawn, then my specimen represents another, and probably a new species.

Dredged in 25 fathoms in North Male Atoll.

40. *Actaea granulata* (And.), 1825. Alcock, III. p. 151.

Dredged in Haddumati, Fadifolu, Mahlos, and South Nilandu Atolls, in 19—50 fathoms. In two cases taken in coral stocks (one alive, one dead). Possibly it lives in such positions, rather than under stones.

41. *Actaea flosculata* Alc., 1898. Alcock, III. p. 151.

Taken on the reef in Miladumadulu and dredged in Suvadiva and South Nilandu Atolls, in 19—38 fathoms. One of the South Nilandu specimens is noted to have come from a block of *Pocillopora*. Neither this nor the species akin to it seem suited to an exposed life.

42. *Actaea spinosissima* n. sp. (Fig. 55).

Diagnosis: "An *Actaea* nearly akin to *A. flosculata*, but with the following differences from that species: (1) Only the spines on the back have the characteristic petaloid shape. Those at the sides and on the limbs are sharp thorns. (2) The posterolateral edge of the back is not marked by a row of small beads, as in *A. flosculata* and in *A. perspinosa* (see below). (3) The hinder edge has a thickened rim, which is wanting in the above-mentioned two species, and the whole arrangement of the tubercles on the field behind the post-gastric

furrow is different, as will be seen by comparing the figures. (4) The peculiar tubercles on

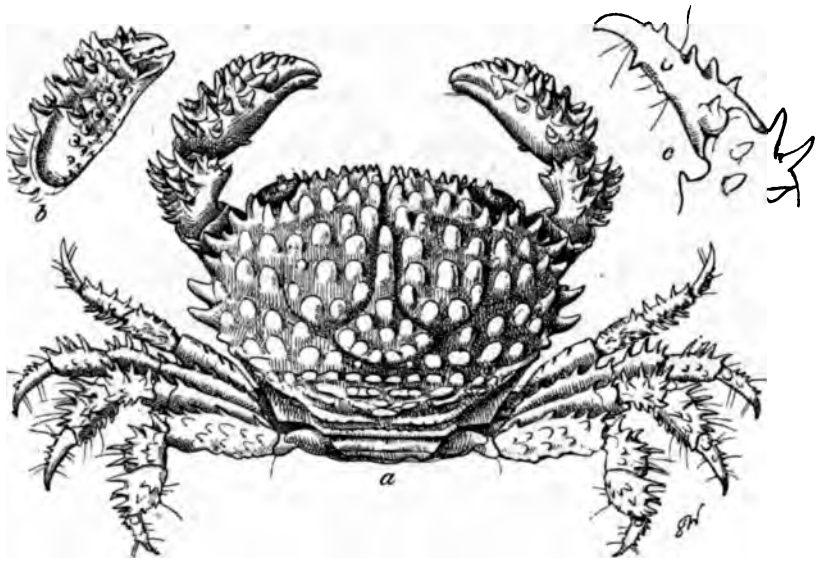

FIG. 55. *Actaea spinosissima*; *a.* whole animal, *b.* outside of hand, *c.* end of walking leg enlarged.

the outside of the hand of *A. flosculata* are replaced in *A. spinosissima* by sharp thorns, and the teeth on the apposed edges of the fingers are less stout."

Length: 4 mm. Breadth: 5·2 mm. Colour in spirit: white.

Dredged in Mahlos Atoll, in 23 fathoms.

43. *Actaea perspinosa*, n. sp. (Fig. 56).

Diagnosis: "An *Actaea* nearly akin to *A. flosculata*, but differing from it in that, in place of the characteristic petaloid spines of the latter species, it is covered with stout, sharp thorns of an entirely different shape."

From *A. spinosissima* it differs in the points indicated above, and from *A. acantha* A.-M. Edw., 1861, and *A. hystrix* Miers, 1886, in the greater size and smaller number of the spines.

Length: 4 mm. Breadth: 5·5 mm. Colour in spirit: pure white.

Dredged in Miladumadulu Atoll in 25 fathoms.

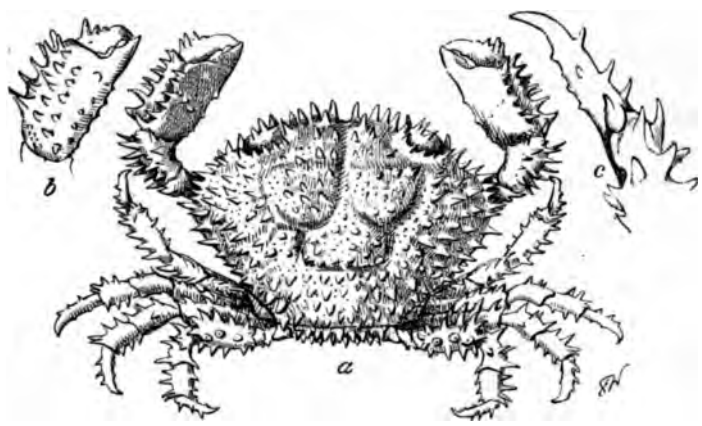

FIG. 56. *Actaea perspinosa*; *a.* whole animal, *b.* outside of hand, *c.* end of walking leg enlarged.

44. *Actaea fossulata* (Girard), 1859. Alcock, III. p. 148. (Fig. 41 *A*.)

The bridge across the hollow on the carpopodites of the walking legs is not always to be found.

Taken on the reef at Hulule, Male Atoll, and in Funadu Velu, Miladumadulu.

45. *Actaea cavipes* (Dana), 1852. Alcock, III. p. 147.
Dredged in the lagoon at Minikoi, in 7—9 fathoms.

Genus *Daira* de Haan, 1833.

46. *Daira perlata* (Hbst.), 1790. Alcock, III. p. 155.
Taken on the shore in Minikoi and Goifurfehendu Atolls.

Genus *Lophozozymus* A. M.-Edw., 1863.

47. *Lophozozymus dodone* (Hbst.), 1801. Alcock, III. p. 108.
Dredged in 4 fathoms in Male Atoll.

Genus *Zozimus* Leach, 1818.

48. *Zozimus aeneus* (Linn.), 1764. Alcock, III. p. 164.
Taken on the shore in Male and Minikoi Atolls.

Genus *Lophactaea* A. M.-Edw., 1862.

49. *Lophactaea anaglypta* (Heller), 1861. Alcock, III. p. 102.
Taken on the reef at Hulule, Male Atoll.

50. *Lophactaea cristata* A. M.-Edw., 1865. Alcock, III. p. 100.
Taken in Funadu Velu, Miladumadulu Atoll.

51. *Lophactaea fissa* Henderson (1893). Alcock, III. p. 103.

Alcock seems to have overlooked the fact that, besides the wide gaps in the side edge of the carapace, this species is separated from *L. granulosa* by the presence of a thick coating of long yellow hairs. No doubt because this coating hides the granules of the carapace it is not shown in Henderson's figure (*Tr. Linn. Soc. Zool.* 2. v., pl. XXXV. fig. 8), though he describes it.

Taken on the reef at Goidu, Goifurfehendu Atoll.

52. *Lophactaea granulosa* (Rüppell), 1830. Alcock, III. p. 101.
Dredged in Felidu and South Male Atolls.

53. *Lophactaea semigranosa* (Heller), 1861. Alcock, III. p. 101.
Taken in Funadu Velu, Miladumadulu Atoll.

Genus *Atergatis* de Haan, 1833.

54. *Atergatis floridus* (Rumph). Alcock, III. p. 98.
Taken on the reef at Hulule, Male Atoll, under stones.

Subfamily **Carpilinae.**

Genus *Phymodius* A. M.-Edw., 1863.

55. *Phymodius ungulatus* (H. M.-Edw.), 1834.

Phymodius ungulatus, Ortmann, *Zool. Jahrb. Syst.* VII. p. 464 (1893); Alcock, III. p. 162 (1898).

Phymodius monticulosus, Alcock, III. p. 163 (1898).

I am quite unable to distinguish between these species, or to assign my specimens to either of them rather than to the other. All the characters vary, as it seems independently, and the descriptions given by several authors do not always agree. Until examination of a long series of full-grown males have shown whether there exist varieties corresponding to the above two names, and if so exactly in what points they differ, I prefer to follow Ortmann in joining the species absolutely, without keeping varietal names.

These crabs, which were taken on the reef in Hulule and Goifurfehendu Atolls and in lagoons in 3—7 fathoms in Minikoi and Miladumadulu Atolls, live in coral stocks and under stones.

56. *Phymodius sculptus* (A. M.-Edw.), 1873. Alcock, III. p. 164.

Taken on the reef in Male and Goifurfehendu Atolls.

Genus *Chlorodius* H. M.-Edw., 1834.

The members of this genus are often found in coral stocks.

57. *Chlorodius laevissimus* Dana, 1852. Alcock, III. p. 161.

In one specimen the teeth on the inner side of the fingers are wanting in the small chela and obsolescent in the large. The colour of many specimens is yellow, rather than white.

Taken on the reef in Goidu and Fadifolu Atolls, and dredged in South Nilandu and Mahlos Atolls in 22—25 fathoms.

58. *Chlorodius barbatus* Borradaile, 1900. (Fig. 41 *D.*)

Chlorodius barbatus, Borradaile, *Proc. Zool. Soc.* 1900, p. 587, pl. XLI. fig. 4 (1900).

Taken on the reef, and in lagoons down to 9 fathoms, in Minikoi, Goifurfehendu, and Miladumadulu Atolls.

59. *Chlorodius niger* (Forsk.), 1775. Alcock, III. p. 160.

Taken in Male, Fadifolu, Goifurfehendu, Felidu, North Male, and Minikoi Atolls on the reef and in lagoons down to 25 fathoms.

Genus *Euxanthus* Dana, 1851.

60. *Euxanthus exsculptus* (Hbst.), 1790; var. *rugosus* Miers 1884. (Fig. 41 *C.*)

Euxanthus melissa, Alcock, III. p. 110.

Since Miers speaks of a specimen of some size, it is likely that this is at least a variety,

and not merely a young form. I am inclined to think that it will prove to be a distinct species. The specimen before me measures 14 mm. in length and 21 in breadth. The brown colour of the fingers does not spread over the palm. Taken on the reef at Hulule, Male Atoll.

Genus *Carpilodes* Dana, 1851.

61. *Carpilodes stimpsoni*, A. M.-Edw., 1865. Alcock, III. p. 82.

Taken on the reef at Goidu, Goifurfehendu Atoll.

62. ? *Carpilodes pediger* Alc., 1898. Alcock, III. p. 83.

Two small male specimens in the collection may either be the young of this species or belong to *C. ruber*. The colour is that of *C. pediger*. They were dredged in Miladumadulu and Fadifolu Atolls in 20 and 23 fathoms respectively.

63. *Carpilodes ruber* A. M.-Edw., 1865.

Carpilodes ruber, A. Milne-Edwards, *Norw. Arch. Mus.* p. 228, pl. XI. fig. 4 (1865).

Dredged in 25 fathoms in South Nilandu Atoll.

64. *Carpilodes vaillantianus* (A. M.-Edw.), 1862. Alcock, III. p. 85.

Taken on the reef in Male and Goifurfehendu Atolls, in Funadu Velu, Miladumadulu, and in Minikoi lagoon. In the latter locality a specimen was found among the leaflets of the *Halimeda*-weed, where its bright red colour could not be in the least protective.

65. *Carpilodes monticulosus* A. M.-Edw., 1873. Alcock, III. p. 86.

This species, which lives under stones, was taken on the reef at Male, Goifurfehendu, and Minikoi Atolls.

66. *Carpilodes pallidus* Borradaile, 1900.

Carpilodes pallidus, Borradaile, *Proc. Zool. Soc.* 1900, p. 586, pl. XL. fig. 1.

This species is allied to *C. monticulosus* and to *C. cariosus*. It differs from the former in that: (1) There is no narrow transverse ridge behind the mesogastric lobule. (2) The furrows of the carapace are not so deep. (3) The colouring is quite different.

From *C. cariosus* it differs in that: (1) The lobules are not pitted, and the carapace has therefore not a worm-eaten appearance. (2) There is no transverse ridge behind the mesogastric lobule, and the branchial lobules are not broken up into smaller ones. (3) The furrows between the lobules are rather shallow. (4) Counting the groove which marks off the mesogastric lobule and that which runs within the hinder edge, there are altogether three grooves behind the lobule in question, but the middle of the three is shallow, and may consist of two separate dimples, hardly connected across the middle line. (5) The notch between the first two lobules of the edge may be rather indistinct. (6) The pink colour of the legs does not tend to orange (as in most of my specimens of *C. cariosus*), and even in the most brightly coloured specimens there is no trace of colour on the carapace.

Taken on the reef at Hulule, Male Atoll.

67. *Carpilodes cariosus* Alc., 1898. Alcock, III. p. 86.

The colour in most of my specimens is not pink but orange-yellow[1]. One small male from Miladumadulu, however, exactly agrees with Alcock's description of the colouring, and at the same time differs from the yellow-marked specimens in having less extensive patches of colour on the back, and in that the lobules of its carapace are somewhat more compact and less irregular in shape. It is possible that this is the true *C. cariosus*, while the other specimens belong either to a distinct species or to a variety.

Dredged in Miladumadulu, Suvadiva, Mahlos, Fadifolu, Male, and South Nilandu Atolls, in 20—40 fathoms.

Genus *Carpilius* Desm., 1825.

68. *Carpilius maculatus* (Linn.), 1764. Alcock, III. p. 79.

This species was seen both at Minikoi and in the Maldives. It may be found wedged into holes on the reef, just above low water-mark, exposed to the full force of the surf.

69. *Carpilius convexus* (Forsk.), 1775. Alcock, III. p. 80 (Fig. 41 *B*, 42 *A*).

Taken in Fadifolu, Male, Minikoi and North Male Atolls on the reef and in lagoons down to 35 fathoms.

Subfamily **Etisinae.**

Genus *Chlorodopsis* A. M.-Edw., 1873.

70. *Chlorodopsis spinipes* (Heller), 1861. Alcock, III. p. 169.

Taken on the reef in Male and Minikoi Atolls.

71. *Chlorodopsis woodmasoni* Alc., 1898. Alcock, III. p. 171.

Taken on the reef in Male, Fadifolu and Goifurfehendu Atolls, and dredged in 6 fathoms in Male Atoll.

72. *Chlorodopsis frontalis* (Dana), 1852.

? *Etisodes frontalis*, Dana. *U.S. Expl. Expd. Crust.* I. p. 187, pl. IX. fig. 3 (1852).

[Not *Etisodes frontalis*, Borradaile, *Proc. Zool. Soc.* 1900, p. 588 (1900) = *Leptodius sanguineus* H. M.-Edw., 1834, juv.]

The collection contains specimens of a crab which resembles Dana's species in all but the following points: (1) The forepart of the carapace derives its roughness, not from minute granules, but from minute dimples. (2) The carapace is a little broader than in Dana's figure. (3) The chelipeds are not entirely "unarmed," for the wrist bears two blunt teeth on the inside.

The front and the upper edges of the legs of the last four pairs are finely toothed. The fore edge of the meropodite of the third maxilliped is but slightly hollowed. The length of the carapace is very little more than $\frac{3}{4}$ of the breadth.

I have placed this species in the genus *Chlorodopsis* because the fronto-orbital breadth is a little *more* than half the greatest breadth, and because of the outline of the fore edge of the meropodite of the third maxilliped. The front is not broad enough to justify its being

[1] *C. vailliantianus* also often tends to orange rather than crimson, when preserved in spirit.

placed in the subgenus *Cyclodius*, being *less* than half the breadth of the carapace. In any case the species seems to be a transitional one.

The specimens mentioned under the name of this species in the *P. Z. S.* for 1900 were small individuals of *Leptodius sanguineus*.

Taken on the reef on Male Atoll and dredged in 25 fathoms in South Nilandu Atoll.

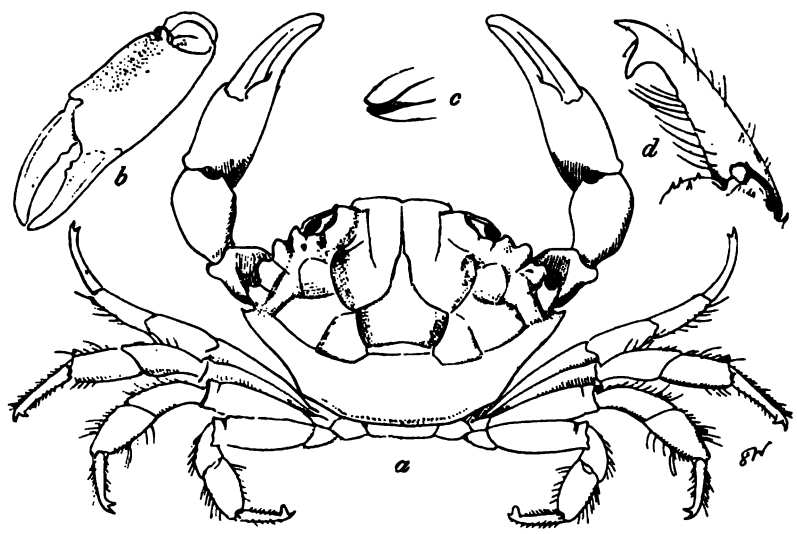

FIG. 57. *Chlorodopsis espinosus*; *a*. whole animal, *b*. outside of hand, *c*. ends of fingers to show hoof-like tips, *d*. end of walking leg enlarged.

73. *Chlorodopsis espinosus*, n. sp. (Fig. 57).

Diagnosis: "A *Chlorodopsis* whose length is just under $\frac{3}{4}$ of the breadth, the carapace hairless, of even surface but minutely granular, areolated as in *C. frontalis* (Dana); the front slightly arched, slightly notched in the middle, with thickened edge; the anterolateral edge with five sharp teeth (including the orbital angle), of which the two hindermost are thorn-like; the hinder edge slightly arched; the orbital gap very narrow, so that the prolongation of the basal joint of the antenna is hard to see; the fore edge of the meropodite of the third maxilliped only slightly concave, with a small projection at its inner end; the chelipeds equal, without tubercles or thorns except one sharp thorn at the inner angle of the wrist, the hand narrow, with a faint groove above and a groove down each finger, the fingers as long as the upper edge of the palm, gaping, with a few sharpish teeth and hoof-like ends; and the walking legs hairy, with spines on the end-joints, and a double end-claw."

Length: 8 mm. Breadth: 12 mm. (Largest specimen.) Colour in spirit: white; the fingers brown with white tips.

This species differs from most *Chlorodopsis* in the absence of spines from the back and chelipeds.

Taken in Funadu Velu, Miladumadulu Atoll.

74. ? *Chlorodopsis* (*Cyclodius*) *ornata* Dana, 1852. Alcock, III. p. 171.

I have assigned several small specimens to this species, but am uncertain whether they are not really the young of *Phymodius ungulatus*. They agree with Alcock's definition, except

in that the basal joint of the antenna does not fill the orbital gap, though the flagellum is not placed at its apex, a small process extending inwards towards the orbit as shown in Dana's figure (*U. S. Expl. Expd. Crust. Atlas*, Pl. XII. figs. 11 c, 11 d).

Taken on the reef in Male, Goifurfehendu and South Mahlos Atolls.

Genus *Etisodes* Dana, 1851.

75. *Etisodes anaglyptus* (H. M.-Edw.), 1834. Alcock, III. p. 133.

Taken on the reef in Goifurfehendu Atoll and dredged in 3—9 fathoms in Minikoi lagoon.

76. *Etisodes electra* (Hbst.), 1801. Alcock, III. p. 133.

In young specimens the lobes of the front are shorter, and not so equal as in old individuals, the middle lobes being distinctly broader than the outer. I doubt the specific distinctness of this form from *E. anaglypta.*

Taken on reefs and in lagoons in Male, Goifurfehendu, Miladumadulu, Fadifolu and Minikoi Atolls.

Genus *Etisus* H. M.-Edw., 1834.

77. *Etisus laevimanus* Randall, 1839. Alcock, III. p. 131.

Alcock quotes only figures 1 a—b on Dana's plate X., seeming thus to exclude figs. 1 f—h, which Dana labels as young females of the same species. My specimen, a female, exactly resembles these latter figures.

Taken on the reef at Hulule, Male Atoll.

Subfamily **Eriphiinae.**

Genus *Domecia* Eyd. and Soul., 1841.

78. *Domecia hispida* Eyd. and Soul., 1841 var.? (Fig. 41 e.) See Alcock, III. p. 230.

My specimens agree with the figures and descriptions of *D. hispida,* but have no hairs on the carapace.

This is a true coral crab, like *Trapezia* and *Melia,* and lives among the branches of living corals. It was taken on the reef at Goidu, Goifurfehendu Atoll, and seen also in Minikoi.

Genus *Eriphia* Latr., 1817.

79. *Eriphia laevimana* Latr., 1817. Alcock, III. p. 214.

This species, which was taken at Minikoi, lives in holes in the rocks and is rather active in its movements.

80. *Eriphia scabricula* Dana, 1852. Alcock, III. p. 216.

Taken on the reef in Minikoi and Addu Atolls. Lives under stones and in coral stocks.

Subfamily **Trapeziinae.**

This group of little, square-bodied crabs, with a broad front and a smooth, usually polished, cuticle (Figs. 41 f, 56), is very characteristic of the Indopacific region, to which its members

are restricted, and within which they are everywhere abundant on coral reefs. They find shelter on various sessile animals, especially branched corals, from which they are usually not to be dislodged except by breaking up the stock, and it is very remarkable that they are found only on living corals, and in these only on those branches which are still alive. Yet they do not eat or in any way damage their host, contenting themselves with deriving protection from its stinging-cells[1]. In correspondence with this habitat, their legs are rather slender, and have end-joints which can be moved through a considerable arc, so as to form with the next joint a kind of hook, serviceable for grappling the branches of the host. These end-joints (Figs. 42 *B*, 58 *c*) are remarkable and interesting structures when the habitat of the crabs is borne in mind. Besides the peculiar flange working on the joint before, which has been described above on p. 242, and is probably an adaptation to clambering, there are several other modifications, which seem intended to give the animals a better foothold on the rugged and yet slimy surface of the coral. Thus the joint is covered with hairs, and among these are a number of stout, moveable prickles. The claw at the end of the joint is bent sharply forming a hook, and is smooth and pointed in *Quadrella*, while in *Trapezia* it is broad and shovel-like, and bears above two rows of structures resembling the prickles but rounded at the end. It is likely that the smoothness of the bodies of these crabs is due to the same cause as that of other semiparasitic Decapods, such as the mussel-prawns and crabs (*Pontonia* and *Pinnotheres*), and that this cause is the need of inconveniencing as little as possible the animals which give them shelter. *Trapezia* and *Tetralia* especially affect corals, but *Quadrella* has been taken on Alcyonarians of various kinds, and even among pearl-mussels[2].

The Trapeziinae are exceptional among Xanthids on account of their tendency to form varieties, and present the feature, unusual in crabs, of definite colour forms. It is possible that some of these forms may be physiological phenomena of the same kind as the colour-phases of prawns[3], but others are associated with structural features, and cannot well be of this nature. It is also important to note that, in *Trapezia*, they bear no relation to the colour of the coral. For the present it were well that none of them were overlooked, and I have therefore revived, in two cases, colour names which had been dropped, without, however, intending any implication as to the nature of the phenomena.

The synonymy of this group is extremely intricate, and the authority followed here is Ortmann, in his late revision [*Zool. Jahrb. Syst.* x. ii. p. 201 (1897)].

Genus *Trapezia* Latr., 1825.

81. *Trapezia ferruginea* Latr., 1825 (Fig. 41 *F*, 42 *B*).

i. Var. *typica* Ortm., 1897, Alcock, III. p. 220.

On reefs and in lagoons down to 35 fathoms in Goifurfehendu, Male, Fadifolu, Addu, Minikoi, South Nilandu, Suvadiva, and South Male Atolls.

ii. Var. *dentata* (Mackay), 1838. Ortmann, *loc. cit.* p. 204.

On reefs at Male, Goifurfehendu and Fadifolu Atolls and in Suvadiva lagoon in 25 fathoms.

[1] I am much obliged both to Mr Stanley Gardiner and to Mr Forster Cooper for information confirming these statements. From first to last a very large number of coral stocks were broken up by the members of the expedition, and in none of these were *Trapezias* found anywhere but among the living branches, nor was there any evidence of damage to the coral caused by them.

[2] Smith, *Proc. Boston Soc. Nat. Hist.* XII. p. 288 (1869).

[3] Gamble and Keeble, *Q. J. M. S.* XLIII. Pt. 4.

iii. Var. *guttata* Rüppell, 1830. Alcock, III. p. 221.

On the reef in Goifurfehendu and in the lagoons of Mahlos, Suvadiva and North Male Atolls down to 25 fathoms.

iv. Var. *maculata* (Mackay), 1838. Alcock, III. p. 221.

On the reefs in Goifurfehendu, Male, Fadifolu and Minikoi Atolls, and in the lagoons at Suvadiva and South Nilandu down to 25 fathoms.

82. *Trapezia cymodoce* (Hbst.), 1801. Alcock, III. p. 219.

The name *T. coerulea* was given by Heller in 1861 to specimens of this species in which the blue tinge, found to a greater or less extent in many individuals, was very conspicuous. The intermediate cases, however, between pure brown examples and those in which blue predominates, are so numerous, and form such a complete series, that it is impossible to keep *coerulea* even as a varietal name.

On reefs and in lagoons down to 35 fathoms in Male, Minikoi, Goifurfehendu, Fadifolu, South Nilandu, Suvadiva and Felidu Atolls.

83. *Trapezia digitalis* Latr., 1825. Ortmann, *loc. cit.*

i. Var. *typica* = *T. digitalis*, Alcock, III. p. 222.

Dark-brown specimens.

Taken on the reef at Goidu, Goifurfehendu Atoll.

ii. Var. *formosa* Smith, 1869. (*Proc Bost. Soc. N. H.* XII. p. 286.)

This variety differs so sharply from the dark-brown true *digitalis* that it seems to deserve a separate varietal name. In structure the variety is like *digitalis*, but it somewhat resembles *T. ferruginea* in the shape of the front. This feature, however, varies considerably in *digitalis*. The earliest name for the orange-coloured form is *formosa* Smith. *T. corallina* Gerstaecker, 1856, is a coral-red crab.

84. *Trapezia rufopunctata* (Hbst.), 1790. Alcock, III. p. 222.

Taken on the reef in Male and Fadifolu Atolls, and in 19 fathoms in South Nilandu lagoon.

Genus *Tetralia* Dana, 1851.

85. *Tetralia glaberrima* (Hbst.), 1790. Alcock, III. p. 223.

The black colouring on the front of this species varies in breadth from an almost imperceptible line, through bands of greater breadth, to a suffusion of the whole carapace and limbs with dark coloration, and no purpose would be served by keeping Dana's name *nigrifrons*. But the colouring of the legs will, I think, be found to fall into definite varieties. The walking legs, in short, may be either: (1) Uniformly yellow. (2) Uniformly dark brown. (3) Yellow banded with dark brown across the middle of each joint. (4) Yellow with a sharp black spot at the end of the meropodites and propodites. (5) Yellow with narrow brown longitudinal stripes.

An examination of a long series of specimens would probably give interesting results.

Taken on reefs and in lagoons down to 35 fathoms in Goifurfehendu, Fadifolu, Male, Felidu, and Minikoi Atolls.

Genus *Quadrella* Dana, 1851.

86. *Quadrella coronata* Dana, 1852. Var. *granulosa* n. See Alcock, III. p. 266.

All the specimens of *Quadrella coronata* in the collection belong to a new variety, which differs from the type in the following features: (1) The carapace is distinctly broader than long. (2) The chelipeds are only about 2½ times as long as the carapace. (3) The chelipeds are frosted over with tiny granules set in short rows athwart the limb. On the underside of the hand the granules are less regular in arrangement, and, projecting in profile, give the inner (lower) edge of the hand an irregular, fine denticulation. (4) The colour in spirit is a uniform pale flesh-colour, purplish in places.

By the first three of these features the new variety is allied to var. *maculosa* Alc., but it differs from that variety in the following points: (1) The fore edge of the arm is not serrate, but bears about ten long thorns. (2) The coloration in spirit is different.

The following key shows the principal characters which separate the known varieties of *Q. coronata*:

I. Carapace as long as broad. Chelipeds polished. Colour in spirit uniform milk-white. [Fore edge of arm spined. Chelipeds 2¾ times the length of the carapace.]

Var. A, *type* Dana, 1851.

II. Carapace broader than long. Chelipeds more or less frosted over with granules. More or less colour on the body.

A. Fore edge of arm spined. Colour in spirit uniform pale flesh-colour. [Chelipeds 2½ times the length of the carapace.]

Var. B, *granulosa* n.

B. Fore edge of arm serrate or finely denticulate. Colour arranged in a pattern.

i. Fore edge of arm serrate. Chelipeds 2½ times the length of the carapace. Colour in a network of fine lines.

Var. C, *reticulata* Alc., 1898.

ii. Fore edge of arm finely denticulate. Chelipeds 2¾ times the length of the carapace (?). Colour in tiny purple dots.

Var. D, *maculata* Alc., 1898.

Var. *granulosa* was taken on a Gorgonacean dredged in 39 fathoms in Suvadiva Atoll and on a red Alcyonarian dredged in 25 fathoms in the same Atoll, and was dredged in 23 fathoms in Mahlos Atoll.

87. *Quadrella bispinosa*, n. sp. (Fig. 58.)

Diagnosis: "A *Quadrella* which is near akin to *Q. coronata* but differs from it in the following points: (1) The carapace is distinctly broader than long. (2) There is a spine on the anterolateral edge of the carapace, rather farther from the spine at the outer angle of

the orbit than from that which marks the junction of the antero- and postero-lateral edges, and rather smaller than the latter spine. (3) The upper, inner angle of the orbit is not spiniform, but is somewhat raised. The minute teeth which edge both the upper and lower rims of the orbit are, on this angle, increased in size and set farther apart, so that one or two of them can just be seen with the naked eye. (4) The chelipeds are frosted over with tiny granules as in some varieties of *Q. coronata*. The granules are somewhat larger underneath the hand. (5) The arm is rather shorter than in *Q. coronata*. (6) There are few thorns on the end-joints of the legs, but these joints are very hairy. (7) The colour in spirit is a rich orange-brown, paler on the walking legs and fingers.

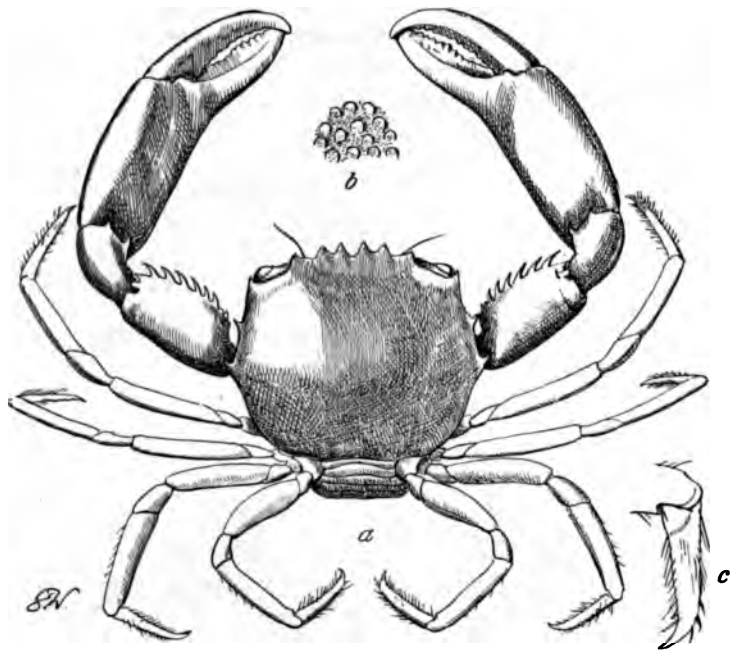

FIG. 58. *Quadrella bispinosa*; *a*. whole animal, *b*. part of outside of hand enlarged to show the scales, *c*. end of walking leg enlarged.

A female with eggs was dredged in 25 fathoms in Addu Atoll.

Subfamily **Oziinae.**

It is somewhat remarkable that the collection contains no example of this subfamily, whose genera (*Ozius*, *Epixanthus*, *Euruppellia* and *Baptozius*) contain several very common species which have been recorded from surrounding localities such as India, Ceylon, the Red Sea, and the Seychelles. Both Alcock (*loc. cit.*) and Ortmann (*Zool. Jahrb. Syst.* VII.) occasionally report species from the Maldives or Laccadives, but neither of them mentions a member of the Oziinae from those islands.

Genera *incertae sedis.*

Genus *Caecopilumnus*, n.

Among the decapods taken on the reef at Naifaro in Fadifolu Atoll is a small, *Pilumnus*-like crab whose orbital region has undergone a remarkable transformation, so that the animal appears to be absolutely blind. In a few words, this transformation consists in the orbits becoming very small, almost on the underside of the carapace, and completely filled by the eyestalks, while the small cornea lies on the underside of the stalk and is hidden in the orbit, so that the outline of the body is quite unbroken over the area where the open orbit should lie.

I propose to establish for this crab a new genus, under the name of *Caecopilumnus*, with the following characters: (1) *Carapace* roughly square, convex both fore and aft and from

side to side, hairy, and granular. (2) *Front* narrow, triangular with rounded apex, hollowed and grooved above. Front-orbital breadth small. (3) *Anterolateral edge* irregularly set with small spines, passing evenly into posterolateral, without orbital angle. (4) *Orbits* small, completely filled by eyestalks, not closed. (5) *Eyes* with relatively large end-joint but small cornea, which is on the underside at the free end. The upper side is granular and hairy like the carapace, but the underside is smooth and its cuticle transparent. (6) *Antennae* with rather

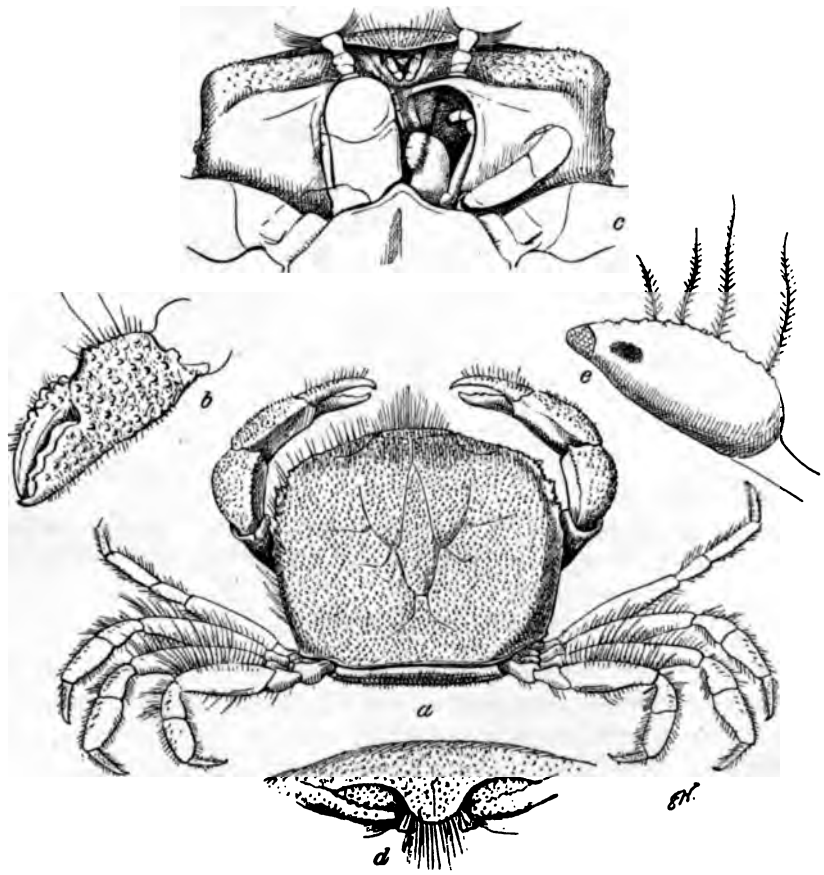

FIG. 59. *Caecopilumnus hirsutus*; *a.* whole animal, *b.* outside of hand, *c.* view of underside with roof of mouth laid bare, *d.* front view to show orbits closed by eyestalks, *e.* underside of eye enlarged, showing small cornea and mass of pigment within stalk. The hairs have been taken off the right side of the body.

broad basal joints, which do not completely fill the orbital gap. (7) *Third maxillipeds* with broad, squarish ischiopodite and meropodite, the latter having its fore edge rounded, and narrow exopodite. The carpopodite is attached distally to the meropodite. (8) *Endostome ridges* present and distinct, but not reaching the fore edge of the mouth. (9) *Chelipeds* equal, granular, with pointed fingers. (10) *Walking* legs stout and of moderate length.

The single specimen being a female, it is impossible to describe the characters of the male.

As to the habits, nothing is known, save that the crab was taken on the reef. There is nothing in its appearance to suggest a parasitic existence except the reduction of its eyes. Probably the peculiar conformation of the orbits is due to some circumstance which makes it

necessary to guard against the entrance of foreign bodies or enemies. Whether the eyestalks can be raised, upon occasion, so that the small eyes are exposed, it is impossible to say, but in the spirit specimen they are certainly so firmly fixed that they cannot be moved without breaking the carapace. The specimen is not well enough preserved to allow of statements being made as to the retina, but a small mass of pigment can be seen through the transparent underside of the eyestalk, at some distance from the cornea.

The systematic position of the genus is doubtful, especially in view of the fact that the male is not known. If it belong to the Xanthidae, it is perhaps more closely related to the Menippinae than to any other subfamily, but it may quite possibly be a Catometope allied to the Rhizopinae, and especially to the species which Miers referred doubtfully to *Typhlocarcinus* under the name *T. integrifrons* [*Ann. Mag. N. H.* (5), VIII. p. 260 (1881)].

1. *Caecopilumnus hirsutus*, n. sp. (Fig. 59).

Diagnosis: "A *Caecopilumnus* with the carapace moderately convex from side to side, strongly so fore and aft, granular and pubescent all over, the front strongly bent downwards, its sides sloping inwards to a groove in the middle, fringed with long hairs, which are also found all over the orbital region and eyestalks and along the sides of the carapace; the orbit very small, without orbital tooth or spine or notches in the rim; the anterolateral edge passing with an even sweep into the posterolateral behind, and in front fading away at a point behind and above the outer angle of the orbit, which thus comes to lie to a great extent on the underside of the body; the granules of the carapace enlarged along the anterolateral edge into small spines, arranged in four irregular sets; the hinder edge hollowed; the regions rather faintly marked; the eyestalks large relative to the orbits, which they entirely fill, fitting close against the thin, non-prominent rims, and thus complete the outline of the carapace, simulating the carapace in their granulation and hairs; cornea small and hidden on the underside of the eyestalk; chelipeds equal, granular, pubescent and hairy, these features extending to the fingers, the fingers compressed and grooved, with interlocking teeth on their apposed edges, and sharp, crossing tips; and walking legs of moderate length, very stout, especially the second and third, which have very long propodites, covered with long hairs but without spines."

Length: 8 mm. Breadth: 9 mm. Colour in spirit: white.

Genus *Maldivia*.

A white Gorgonacean, dredged in eight fathoms of water, in North Male, bore a minute but very interesting symbiotic crab, whose peculiarities justify the setting up of a new genus for it. The following are the characters of this genus: (1) *Carapace* hexagonal, swollen, a little longer than broad, hairless, roughened with granulations which pass into spines at the sides, and with indications of the regions. (2) *Front* broad, triangular, widely grooved, bent strongly downwards. (3) *Anterolateral edge* toothed, about equal to posterolateral. *Hind edge* wavy. (4) *Orbits* large, very slanting, not fully closed. (5) *Abdomen* of male seven-jointed. (6) *Endostome ridges* present, but not very strong. (7) *Eyes* large. (8) *Antennae* with slender basal joints which do not touch the front, and long flagella. (9) *Merus of third maxilliped* about as long as broad, without a notch in the fore edge, which is straight. (10) *Chelipeds* stout, *Pilumnus*-like, fingers not hollowed at the tip. (11) *Walking* legs moderately stout.

The genus resembles *Pilumnus* in the shape of the hands and the endostomial ridges.

The form of the carapace, the presence of endostomial ridges and the symbiotic habits recall *Quadrella*. The front and the spinate region at the side of the granulated carapace, and again the endostomial ridges, show a certain resemblance to *Caecopilumnus* described above, though the eyes and orbits are very different. The form of the antennae points to its true position being among the Menippinae, perhaps in the neighbourhood of *Pilumnus*.

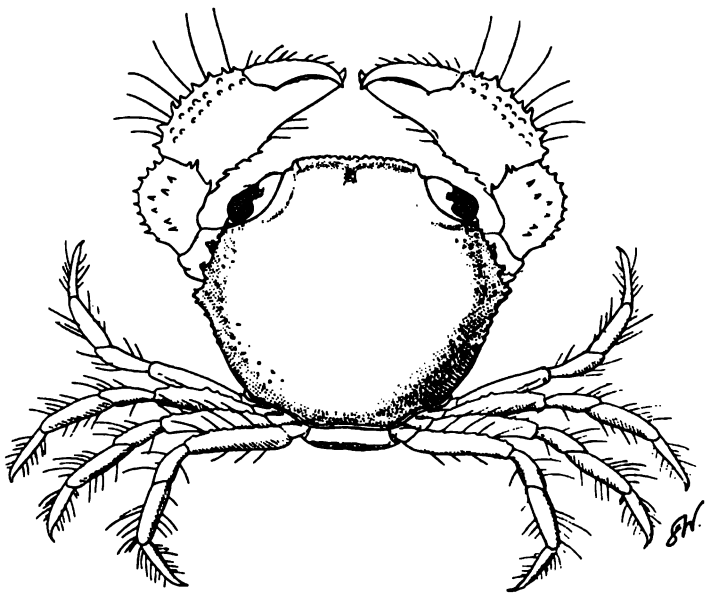

FIG. 60. *Maldivia symbiotica*, found on a gorgonian, whole animal greatly enlarged.

2. *Maldivia symbiotica*, n. sp. (Fig. 60).

Diagnosis: "A *Maldivia* whose carapace is roughened with small tubercles, which in places, as on the anterolateral edge, pass into spines; the latter edge with four lobes, including the orbital lobe, each lobe bearing several spines, of which one is larger than the rest, while the lobes decrease in size from behind forwards; the chelipeds equal, bearing on the outside spines set in rows, a row along the upper edge being specially long, the fingers shorter than the hand; the walking legs moderately stout, bearing some long hairs."

Length: 1·5 mm. Breadth: 1·6 mm. Colour in spirit: white.

Family **Atelecyclidae.**

Subfamily **Thiinae.**

Genus *Kraussia* Dana, 1852.

1. *Kraussia rugulosa* (Krauss), 1843.

Kraussia rugulosa, Dana, *U.S. Expl. Expd. Crust.* p. 302, pl. 19, fig. 1 (1852).

Taken on the reef in Male, Goifurfehendu and Minikoi Atolls.

2. *Kraussia integra* (de Haan), 1837. Alcock, IV. p. 97.

A small specimen from Mahlos Atoll shows characters which recall *K. nitida* Stimps., 1858, in that the frontal lobes are subdivided, though not so deeply as in Stimpson's species, and the carapace is somewhat narrower than in adult specimens of *K. integra*. The teeth on the dactylopodites of the legs are small.

Taken on the reef in Male and dredged in 24 fathoms in Mahlos Atoll.

Family **Hapalocarcinidae.**

This interesting little family of symbiotic crabs, of which, in one case, only the females are known, is, as Calman has shown [*Tr. Linn. Soc. Zool.* (2), VIII. p. 43 (1900)], quite *incertae sedis*, and is taken here for convenience alone, and not on account of any relationship to the Xanthidae. It is discussed at length in Calman's paper. For some remarks on the importance of these crabs as affording by their holes a foothold for destructive boring organisms in the coral blocks, see a paper by Mr Stanley Gardiner in this part of the present publication.

Genus *Hapalocarcinus* Stimps., 1857.

1. *Hapalocarcinus marsupialis* Stimps., 1857. Calman, *loc. cit.*

Galls containing specimens of this crab were found on *Pocillopora* in the lagoon at Minikoi and on the reef at Hulule, Male Atoll.

Genus *Cryptochirus* Heller, 1861.

2. *Cryptochirus coralliodytes* Heller, 1861.

Cryptochirus coralliodytes, Heller, *S. B. Ak. Wiss. Wien*, XLIII. i. p. 366, pl. II. figs. 33—39 (1861); Semper, *Animal Life*, London, 1881, pp. 217, 221—223; Calman, *loc. cit.* p. 47.

Mr Stanley Gardiner has kindly given me the following note on this species: "A block of *Leptoria tenuis* which had a large number of round holes on the surface, up to 4 mm. across, was broken up. The holes, when traced in, were nearly all found to be occupied by a symbiotic crab [*Cryptochirus*]. In two holes, however, were crabs of the ordinary form [*Pseudozius*, see above, p. 241]. The holes varied in depth from 1—30 mm., the coral itself being in the latter position 48 mm. thick. Normally the animal would appear to live close to the surface—some slightly projected, with the carapace as a kind of shield closing the hole. When the block becomes more or less dry, they retreat into the bottom of the holes. I found some deserted holes, perhaps due to an accident in breaking the coral, but the crabs certainly could not wander, on account of the small size of the entrances of the holes. It is obvious that the crab must have taken up its abode on the coral, which afterwards enclosed it. [This refers to the inner hole, not to the funnel round it.] These commensals are extremely common in *Leptoria* from the lagoon at Minikoi, but are never found in specimens from the outer reef. They are rare on other corals, occasionally occurring in massive astraeids from the lagoon at Minikoi, but not apparently in branching corals, fungoids, or perforate corals."

ON THE FISHES FROM THE MALDIVE ISLANDS.

I. DREDGED. II. FRESH-WATER.

By C. TATE REGAN, B.A., *Assistant at the Natural History Museum, S. Kensington.*

The Collection of Fishes from the Maldive Islands has been divided into two series. The first consists of the specimens dredged or trawled within the lagoons of the atolls. The second contains a few specimens taken from fresh-water pools on some of the islands.

The use of formalin as a preservative has rendered the fin rays very brittle, so that in most of the specimens the fins are more or less damaged.

I take this opportunity of gratefully acknowledging my indebtedness to Mr Boulenger, who has very kindly looked through the collection under notice, and confirmed my identifications.

I. DREDGED FISHES FROM WITHIN THE LAGOONS.

There are 321 specimens, belonging to 65 species. They are mostly small, the lagoons probably being nurseries for young fish. This has made identification a very difficult matter in many cases, so that some specimens have been referred only to their genus, and many, which seem without doubt to belong to hitherto undescribed species, have been only briefly described, and have not been given specific names.

A list of the species follows. For convenience of reference I have kept to the arrangement of families in Günther's *Study of Fishes.*

ACANTHOPTERYGII.

Fam. **Percidae.**

1. *Apogon auritus*, C. and V. Suvadiva, 44*f.* (fathoms).

2. *Apogon elliotti*, Day. (*Apogon nigripinnis*, Gthr. (Part); *Apogon arafurae*, Gthr.)

Günther identified specimens belonging to this species with *Apogon nigripinnis*, C. and V., and later described a somewhat large specimen from the Challenger Collection as a new species.

Apogon arafurae[1]: Day distinguishes between this species and *Apogon nigripinnis*, C. and V., from which it differs in many important characters.

In the specimens in the British Museum Collection, and in those from the Maldives, the length of the snout is $\frac{2}{3}$ to $\frac{3}{4}$ of the diameter of the eye, and in the Challenger specimen, described as *Apogon arafurae*, the eye diameter is equal to the length of the snout, which is contained 4 times in the length of the head, this being due to the fact that the eyes become relatively smaller in larger fish. Day's statement that the length of the snout is $\frac{1}{2}$ the diameter of the eye is probably, therefore, inaccurate.

Suvadiva, 44 *f.*, and Mulaku, 27 *f.*

3. *Apogon nigripinnis*, C. and V. Haddumati, 40 *f.*

A male fish, 47 mm. in total length, had its mouth full of eggs; and a specimen in the British Museum Collection shows the same phenomenon, which is, no doubt, a case of protection by the parent.

4. *Apogon septemstriatus*, Gthr. S. Nilandu, 36 and 30 *f.*

5. *Apogon fasciatus*, White. S. Nilandu, 30 *f.*

6. *Apogon* sp. N. Male, 35 *f.*

D. VII, 19; A. II, 8; L. lat. about 25.

This species is represented by two very small specimens, each 15 mm. in total length. The head is nearly half the total length. The body is dark brown, with a black band at the base of the dorsal, and a broad black longitudinal band ventrally. They cannot with certainty be said to belong to a hitherto undescribed species.

7. *Anthias cooperi*, n. sp.

D. x, 16; A. III, 7; Sc. 52, $\frac{3}{15}$; L. lat. 50.

Depth of body three times in total length, length of head $3\frac{1}{3}$ times. Snout scaly, shorter than the eye, the diameter of which is slightly greater than the interorbital width, and is contained three times in the length of the head. Lower jaw slightly projecting, scaly. Maxillary scaly, extending to below the centre of the eye, the width of its extremity $\frac{2}{3}$ the diameter of the eye. Two or three spines at the angle of the preopercle; sub- and interopercle serrated; two opercular spines. Dorsal spines increasing in length to the fourth, rest subequal; no notch between spinous and soft portions; base scaly. Ventrals a little longer than the pectorals, not quite so long as the head. Anal spines strong, the first shortest, the second longer than the third; soft portion scaly at the base, pointed, the third ray longest. Caudal moderately emarginate. Caudal peduncle as long as deep. Lateral line curved. Coloration uniform, in spirit.

This species is allied to *Anthias cichlops*, *squamipinnis* and *townsendi*, from all of which it differs in having more numerous scales, and in having spines at the angle of the preopercle; in this latter feature it resembles *Anthias formosus* and *margaritaceus*, from which it differs in the important character of having the lateral line curved, not forming an angle below the hinder dorsal rays. Length of the specimen, 47 mm.

Haddumati, 40 *f.*

[1] Day, *Fishes of India*, I. pp. 60 and 63.

8. *Epinephelus sexfasciatus*, C. and V.

Three specimens less than 30 mm. in total length have a prominent spine at the angle of the preopercle, equal in length to ½ the diameter of the eye. A somewhat larger specimen, 48 mm. long, has the normal adult arrangement.

Haddumati, 35 *f.*

Fam. **Mullidae.**

9. *Upenoides tragula*, Richardson. Mulaku, 27 *f.*

Fam. **Cirrhitidae.**

10. *Cirrhitichthys oxycephalus*, Blkr. Haddumati, 40 *f.*

Fam. **Scorpaenidae.**

11. *Cocotropus roseus*, Day. N. Male, 35 *f.*

12. *Minous monodactylus*, Bl. Schn. S. Nilandu, 36 *f.* N. Male, 35 *f.*

13. *Pelor didactylum*, Pall. Suvadiva, 30 *f.*

14. *Amblyapistus macracanthus*, Blkr. Suvadiva, 30 *f.*

15. *Pterois zebra*, C. and V. Haddumati, 35 *f.*, and Kolumadulu, 35 *f.*

Fam. **Acanthuridae.**

16. *Naseus* (? *Keris*) sp. Suvadiva, 37 *f.*

D. VI, 29; A. II, 30.

A single specimen, 37 mm. in total length, closely resembles *Keris amboinensis*, Blkr., but differs in having the first dorsal spine longer than the others. Probably, like *Keris amboinensis*, it is the young form of a species of *Naseus*.

Fam. **Trachinidae.**

17. *Percis punctulata*, C. and V. N. Male, 35 *f.*

18. *Champsodon vorax*, Gthr. Suvadiva, 30 *f.*, and Mulaku, 27 *f.*

19. *Percophis* sp.

D. VII or VIII, 30—35; A. 30—35; Sc. 52.

A single badly preserved specimen, 35 mm. in total length, undoubtedly belongs to this genus, which has not before been known to occur in the Indian Ocean, only one species, *Percophis brasilianus*, from the coast of Brazil, having been described.

Depth of body 12 times in the total length, length of head four times. A longitudinal band along the middle of the side. The shape and proportions of the body are exactly the same as in *Percophis brasilianus*, which has, however, much smaller scales.

Kolumadulu, 33 *f.*

Fam. **Pediculati.**

20. *Antennarius nummifer*, Cuv. Haddumati, 35 *f.*

Fam. **Cottidae.**

21. *Platycephalus asper*, C. and V. Mulaku, 27 *f.*, and N. Male, 35 *f.*

22. *Platycephalus tuberculatus*, C. and V. Kolumadulu, 35 *f.*, and Haddumati, 40 *f.*

23. *Platycephlus spinosus*, Schleg. Kolumadulu, 35 *f.*

In this specimen, as in that in the British Museum Collection, the number of scales in a longitudinal series is 33, not 40 as given by Schlegel.

24. *Platycephalus subfasciatus*, Gthr. Mulaku, 27 *f.*

Fam. **Cataphracti.**

25. *Pegasus draconis*, Linn. Haddumati, 40 *f.*

Fam. **Gobiidae.**

26. *Gobius caninoides*, Blkr. Mulaku, 27 *f.*

27. *Gobius ornatus*, Rüpp. S. Nilandu, 36 and 30 *f.*, Felidu, 34 *f.*, Mulaku, 27 *f.*, and Kolumadulu, 33 *f.*

28. *Gobius semidoliatus*, C. and V. N. Male, 35 *f.*

29. *Gobius ophthalmotaenia*, Blkr. S. Nilandu, 36 *f.*, and N. Male, 35 *f.*

30. *Periophthalmus* sp. S. Nilandu, 35 *f.*

One specimen, 33 mm. long. The ventral fins are not united. Probably a young specimen of *Periophthalmus chrysospilos.*

31. *Callionymus longicaudatus*, Schleg. S. Nilandu, 36 and 30 *f.*

32. *Callionymus lunatus*, Schleg. Suvadiva, 44 *f.*, and Haddumati, 40 *f.*

33. *Callionymus* sp. Suvadiva, 37 *f.*

D. IV, 7; A. 6. Length of the head about three times in the total length. Gill opening small, superior. Preopercular spine with four posterior teeth. Eye diameter about three times in the length of the head. Brownish, with darker bands or blotches, and with a series of narrow transverse bands on the gill membranes. The single specimen is 24 mm. in total length, and probably belongs to a hitherto undescribed species.

Fam. **Blenniidae.**

34. *Petroscirtes* sp.

D. 26; A. 16. This fish was dredged at Berriamfuri, N. Mahlos, in the lagoonlet, at a depth of four fathoms, in a Gastropod shell. Mr Gardiner says, "I kept this fish alive for some hours in a basin, it would swim round, always returning to its house. The favourite position was with the head just projecting out of the mouth of the shell."

The specimen is 28 mm. long.

35. *Clinus* sp. Haddumati, 40 *f.*

D. 24; A. 16; V. i, 3; Sc. 30, 11.

The depth of the body is equal to the length of the head and is contained 3½ times in the total length. Snout shorter than the eye, the diameter of which is twice the interorbital width, and is contained 3⅔ times in the length of the head. The single specimen is 30 mm. in total length, and probably belongs to a species not before described, and differing from nearly all other species of *Clinus* in the large size of the scales.

ACANTHOPTERYGII PHARYNGOGNATHI.

Fam. **Pomacentridae.**

36. *Dascyllus melanurus*, Blkr. Felidu, 34 *f.*

37. *Amphiprion sebae*, Blkr. S. Nilandu, 30 *f.*, and N. Male, 35 *f.*

38. *Pomacentrus punctatus*, Quoy and Gaim. Suvadiva, 43 *f.*, and Haddumati, 40 *f.*

Fam. **Labridae.**

39. *Labroides dimidiatus*, C. and V. Felidu, 34 *f.*

40. *Julis schwanefeldii*, Blkr. Mulaku, 27 *f.*

41. *Cheilinus* sp. Mulaku, 27 *f.*

Four specimens 28—45 mm. long may be young specimens of *Cheilinus calophthalmus.*

42. *Cheilinus* sp. Mulaku, 27 *f.*, and N. Male, 35 *f.*

Several young specimens less than 30 mm. long may belong to *Cheilinus ceramensis.*

43. *Cheilinus* sp. Suvadiva, 43 *f.*

Two very small specimens may belong to *Cheilinus celebicus.*

ANACANTHINI.

Fam. **Pleuronectidae.**

44. *Rhomboidichthys grandisquamis*, Schleg.

Describing this species[1], Schlegel says, "The pectorals are not elongated. The males have a spine on the maxilla and another on the anterior margin of the lower eye. The interorbital width is equal to the diameter of the eye in the males, and is half the diameter of the eye in females. The body is more elongated in the females."

With regard to these features in the specimens from the Maldives: The pectorals are elongated in some, and not in others, without relation to size or sex. All the males have a maxillary spine, but some are without an antorbital spine. The females have neither spine. The interorbital width varies from ¾ to 1½ diameters of the eye in males, and ⅓ to ½ diameter in females, and, as a rule, the eyes are relatively further apart in the larger specimens. The greatest depth of the body is not more in males than in females, but the eyes being wider

[1] Schleg., *Fauna Japonica, Poiss.*, p. 183.

apart in the former, the head and anterior part of the body is broader, so that the females appear more elongated.

This species is distinguished from *Rhomboidichthys poecilurus*, Blkr., by the absence of a pair of black spots on the caudal, and by the greater size of the maxilla, which is contained $2\frac{2}{3}$ times in the length of the head.

Suvadiva, 44 *f.*, S. Nilandu, 36 and 30 *f.*, Felidu, 34 *f.*, and Mulaku, 27 *f.*

45. *Rhomboidichthys poecilurus*, Blkr. (*Rhomboidichthys grandisquama*, Gthr.; and *Rhomboidichthys spilurus*, Gthr.)

Bleeker, describing this species, gives the number of scales in a longitudinal series as about 45. Günther distinguishes between two species, *Rhomboidichthys grandisquama*, with 40 scales in a longitudinal series, which he identifies with *Rhombus grandisquama*, Schleg., in reality a quite distinct species; and *Rhomboidichthys spilurus*, with 48 scales in a longitudinal series, and the eyes closer together.

In the 13 specimens from the Maldives the scales vary from 40—48 in a longitudinal series, nearly all intermediate numbers being found. The males have a knob on the maxilla, and the interorbital width equal to the diameter of the eye. The females have no maxillary knob, and the interorbital width is about $\frac{1}{2}$ the diameter of the eye. In immature fish the eyes are closer together.

This species is distinguished from *Rhomboidichthys grandisquamis* in that it has a pair of black spots on the caudal, in the middle of the upper and lower margins respectively, and has a smaller mouth, the length of the maxilla being contained $3\frac{1}{3}$ times in the length of the head.

Suvadiva, 44 *f.*, and 34 *f.*

46. *Rhomboidichthys intermedius*, Blkr. Suvadiva, 44 *f.*, and Felidu, 34 *f.*

47. *Rhomboidichthys pantherinus*, Blkr. Suvadiva, 43 *f.*, and S. Nilandu, 36 and 30 *f.*

48. *Brachypleura xanthosticta*, Gthr. Suvadiva, 44 *f.*, and Mulaku, 27 *f.*

49. *Cynoglossus brachycephalus*, Blkr. Mulaku, 27 *f.*

50. *Samaris maculatus*, Gthr. Suvadiva, 45 *f.*

In the Challenger Report this species is described, from one specimen, as having three series of dark spots, five along the dorsal profile, four along the lateral line, and five along the ventral profile. In two small specimens from the Maldives, each 29 mm. in total length, these spots are connected by dark lines, the colour being preserved better.

Samaris cristatus, Gray, differs from *Samaris maculatus* in having a somewhat smaller head and deeper body, and in the elongation of the anterior dorsal rays, but the two specimens in the British Museum Collection have dark spots feebly visible in the same position as in *Samaris maculatus*. These specimens are males, and that named *Samaris maculatus* is a female, and apparently the small specimens from the Maldives are females, so that it seems possible that the differences are not specific, but sexual. The elongation of the anterior dorsal rays is characteristic of the males in the allied genus *Brachypleura*, and in many other fishes of this family.

In *Samaris maculatus* the length of the head is 4 times in the total length, the depth of the body $2\frac{3}{5}$ to 3 times.

In *Samaris cristatus* the length of the head is $4\frac{1}{2}$—5 times in the total length, the depth of the body $2\frac{1}{2}$ times.

51. *Solea poropterus*, Blkr. Mulaku, 27 *f.*

PHYSOSTOMI.

Fam. **Scopelidae.**

52. *Saurus varius*, Lacep. S. Nilandu, 36 *f.* and 30 *f.*, Felidu, 34 *f.*, Kolumadulu, 33 *f.*, and N. Male, 35 *f.*

53. *Saurida nebulosa*, C. and V. S. Nilandu, 36 *f.*, Felidu, 34 *f.*, and N. Male, 35 *f.*

54. *Saurida tumbil*, Bl. Suvadiva, 44 *f.*, Felidu, 34 *f.*, and Kolumadulu, 33 *f.*

LOPHOBRANCHII.

Fam. **Syngnathidae.**

55. *Syngnathus* sp. Haddumati, 35 *f.*

D. 23. Osseous rings 15—16 + 35—40. Length of the head 8 times in the total length. Snout a little shorter than the rest of the head. A bony ridge crosses the opercle. Edges of osseous rings serrated. Dorsal fin commences behind the anus. Brown vertical bands on the body.

Two specimens, each 55 mm. long.

56. *Ichthyocampus belcheri*, Kaup. Suvadiva, 44 *f.*

Fam. **Solenostomidae.**

57. *Solenostoma paradoxum*, Pall. Mulaku, 27 *f.*

Bleeker has described small specimens of a species of *Solenostoma* with a slender snout, in which the caudal peduncle is longer than the base of the second dorsal, and named them *Solenostoma brachyurum*. One of these is in the British Museum Collection. Günther has written in the Museum Catalogue, "Considering that we know nothing of the changes which *Solenostoma* undergoes during its growth, it is to be regretted that Dr Bleeker did not examine these specimens more carefully, but merely attached a new name to them."

The specimen from the Maldives seems undoubtedly of the species *Solenostoma paradoxum*. The snout is more slender and the caudal peduncle relatively longer than in the adult. Probably the badly preserved specimen labelled *Solenostoma brachyurum* in the British Museum Collection also belongs to this species, in which case the changes during growth can be shown thus:

	Total Length	Depth of Snout / Length of Snout	Length of Caudal Peduncle / Base of Second Dorsal
(Specimen in Brit. Mus.)	50 mm.	$\frac{1}{9}$	$\frac{2}{1}$
(Maldive specimen)	67 mm.	$\frac{1}{8}$	$\frac{3}{2}$
(Specimen in Brit. Mus.)	97 mm.	$\frac{1}{6}$	$\frac{7}{5}$

PLECTOGNATHI.

Fam. **Sclerodermi.**

58. *Balistes niger*, Mungo Park. Haddumati, 40 *f.*

59. *Monacanthus nasicornis*, Schleg. Suvadiva, 37 *f.*

60. *Monacanthus oculatus*, Gthr. S. Nilandu, 30 *f.*

61. *Monacanthus choirocephalus*, Blkr. Suvadiva, 43 *f.*, and Mulaku, 27 *f.*

62. *Monacanthus* sp. Suvadiva, 45 *f.*

D. 24; A. 24. Dorsal spine barbed. Ventral spine moveable. The specimen is too small for determination of the species.

63. *Ostracion cornutus*, Linn. N. Male, 35 *f.*

The specimen is 24 mm. long, and differs from the adult in having a well-developed spine on the back, in the lesser development of the antorbital and ventral spines, and in having a more projecting snout. A similar specimen in the British Museum Collection is labelled *Ostracion cornutus*.

Fam. **Gymnodontes.**

64. *Tetrodon* sp. S. Nilandu, 36 *f.*

D. 8 or 9; A. 6 or 7. The back is broad, snout equal in length to the diameter of the eye and also to the interorbital width. A simple perforate nasal tentacle on each side. Body covered with three-rooted spines, except on the tail. Purplish brown above, lighter beneath; small brown spots on the back. The single small specimen almost certainly belongs to a hitherto undescribed species.

65. *Tetrodon valentini*, Blkr. Haddumati, 40 *f.*

II. FISHES TAKEN IN FRESH-WATER POOLS.

There are 14 specimens belonging to 6 species, two of which have not been described before. They are mostly marine fishes which are known to ascend estuaries into fresh-water, or are allied to fishes with this habit, only one being a true fresh-water fish. A list of the species follows.

ACANTHOPTERYGII.

Fam. **Percidae.**

1. *Gerres maldivensis*, n. sp.

D. IX. 10, A. III. 8; Sc. $40\frac{4}{10}$.

Depth of body $2\frac{1}{3}$ times in the total length, length of head $2\frac{3}{4}$ times. The length of the snout is equal to the interorbital width and $\frac{3}{4}$ the diameter of the eye, which is contained $2\frac{2}{3}$ times in the length of the head. The maxilla extends to below the first third

of the eye. The caudal peduncle is nearly as high as long. The second dorsal spine is the longest, and is $\frac{2}{3}$ the length of the head; from it they decrease in length to the fifth, the rest subequal. The second anal spine is longer than the third. Pectorals $\frac{4}{5}$ the length of the head. Ventrals do not quite reach the anal. Caudal deeply forked. Light, with indistinct dark vertical streaks. Length of specimen, 73 mm.

Fishes of this genus commonly ascend estuaries into fresh water. A fresh-water pool, surrounded by mangroves, in the centre of Landu, Miladumadulu Atoll.

Fam. **Gobiidae.**

2. *Gobius criniger*, C. and V.

From the lake, Kendikolu, Miladumadulu Atoll.

Fishes of this species are common in backwaters.

Fam. **Mugilidae.**

3. *Mugil coeruleomaculatus*, Lacep.

Fishes of this genus commonly ascend tidal rivers, and a few, but not those of this species, are entirely fresh-water.

From the mangrove lake, Landu, Miladumadulu Atoll.

PHYSOSTOMI.

Fam. **Cyprinidae.**

4. *Barbus vittatus*, Day.

A true fresh-water fish, from the bathing pool, Hulule, Male Atoll, and from the mangrove lake, Landu, Miladumadulu Atoll.

Fam. **Clupeidae.**

5. *Chanos salmoneus*, Bl. Schn.

Fish of this species ascend rivers, and have been introduced and thrive in fresh-water tanks in India. From the lake, Kendikolu, Miladumadulu Atoll.

6. *Chanos gardineri*, n. sp.

D. 14, A. 9; P. 16, V. 11; Sc. 70—75$\frac{11}{15}$.

Depth of body $4\frac{3}{4}$ times in the total length, length of head $3\frac{1}{4}$ times. Snout shorter than the eye, the diameter of which is equal to the interorbital width, and is contained $3\frac{1}{4}$ times in the length of the head. The scales are enlarged on the back just behind the head, and on the abdomen. Dorsal highest in front, the longest ray $\frac{2}{3}$ the length of the head, margin concave, two rows of scales at the base. Pectorals rounded, more than $\frac{1}{2}$ the length of the head. Ventrals rounded, arising beneath the posterior $\frac{1}{3}$ of the base of the dorsal. Anal scaly at the base, margin concave. Caudal deeply forked, its longest ray equal to the length of the head. Caudal peduncle twice as long as high.

The colour is probably similar to that of *Chanos salmoneus*, but owing to preservation of the specimens in formalin this cannot be certainly stated.

The head is much larger, and the body shorter, not so deep, and less compressed than in *Chanos salmoneus*. The scales are less numerous, and the pectorals and ventrals rounded, not pointed. Of all the supposed species of *Chanos* which have been described under various names, and are now generally regarded as varieties of *Chanos salmoneus*, none are found to correspond with this species. Whenever proportional measurements are given the length of the head is described as $\frac{1}{4}$ of the total length without the caudal, or as $5\frac{1}{2}$ times in the total length with the caudal. The depth of the body is never less than $5\frac{1}{2}$ times in the total length, with the caudal. The pectorals are always described as pointed. In some cases the scales are given as less than 80 in a longitudinal series, *i.e.* in *Chanos pala*, Cantor. and *Chanos orientalis*, Blkr., but this is the only point of agreement. Sometimes no characters of specific importance are given, *e.g.* *Leuciscus zeylonicus*, Bennett.

The conclusion is that this species is very distinct, and has not been described before.

There are three specimens, 116, 104, and 74 mm. in total length, from the north pool of Hulule island, Male Atoll.

THE MARINE TURBELLARIA,

WITH AN ACCOUNT OF THE ANATOMY OF SOME OF THE SPECIES.

By Frank Fortescue Laidlaw, B.A. (Cantab.), *Demonstrator and Lecturer in the Owens College, Manchester.*

(With Plates XIV. and XV. and Text-Figures 61—73.)

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I. SYSTEMATIC LIST, WITH NOTES ON THE ANATOMY OF THE SPECIES.

ACOTYLEA. I. Family Planoceridae.

1. *Planocera armata*, sp. n. (Pl. XV. figs. 10, 11, and 12).

One specimen from 40 fathoms, Suvadiva Atoll. Rubble and broken coral bottom.

Total length about 25 mm., total breadth about 15 mm. Tentacles from ant. margin 5 mm. Mouth aperture about 13 mm. behind anterior margin. Male gonopore about 5 mm. behind mouth. Female gonopore about 1 mm. behind male.

Colour white with small pigmented patches, scattered rather numerously near the dorsal surface. Tentacles about 2 mm. apart, bilobed at the tips; each with a dense cluster of eyes at its base. Brain compact, lying under a median branch of the gut. There is a cluster of eyes over the brain between the tentacles (Fig. 61).

The epidermis is composed of very small cells, crowded with a finely granular secretion. I can find no trace of rhabdites. The basal membrane is thick, and occasionally pierced by processes from gland-cells, lying beneath the integument. The muscle layers consist of a thin, outer, longitudinal layer, followed by two layers of diagonal fibres. These are succeeded by a circular layer which is much thicker on the ventral than on the dorsal side. Lastly on the ventral side only is an inner longitudinal layer.

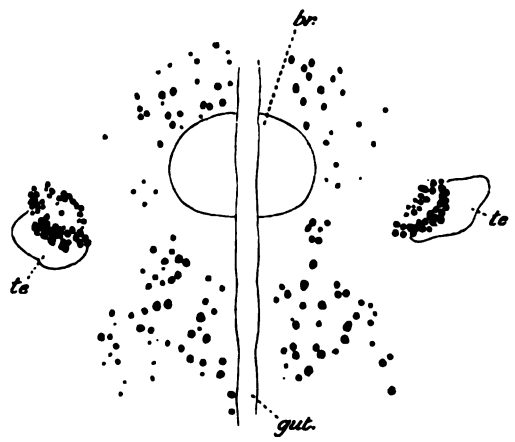


FIG. 61. Eye-spots of *Planocera armata*. *te.* tentacles, *br.* brain.

The pharyngeal aperture is median. From the main gut some seven pairs of gut branches are given off. These again ramify into numerous smaller branches as they run outwards.

The small pigmented patches, referred to in the short account of the external characters given above, are found in section to be due to the presence of dark bodies in certain remarkable, dorsal diverticula given off from the gut branches (Pl. XV. fig. 10). The gut branches themselves are lined with very elongated columnar epithelial cells lying on a delicate basal membrane from which they are frequently, in my sections at least, torn away. The epithelium of the diverticula on the other hand, though similar in appearance, is structurally much reduced and obscured by the dark bodies referred to above.

These dark bodies are of three kinds. Firstly, there are numerous rather large, black, spherical bodies, which are evidently produced in the gut epithelium itself. With a high power different stages of the development of these bodies are readily distinguishable. They commence as small, lightly-staining masses, which increase in size, and at the same time take a deeper stain. Of their ultimate fate nothing can be said at present. They are scattered pretty regularly through the gut tissue and probably have but little or no share in giving the diverticula their characteristic appearance. Secondly, in and about the diverticula there are small masses of little rod-shaped bodies, probably bacteria. These do not occur generally throughout the gut, but only in the diverticula themselves or in their immediate neighbourhood; in the latter case they invariably have an appearance of streaming into the diverticula. Lastly, I have found in one or two diverticula only, a quantity of exceedingly fine, granular, pigment-like substances.

The significance of these bodies and of the diverticula themselves is obscure. The latter may be compared directly with the gut diverticula of such a form as *Thysanozoon brocchii*. Diverticula of a precisely similar character occur in a species of *Planocera*, as yet undescribed, collected by Mr Gardiner at Rotuma, whilst Lang's [9] figure of *Pl. villosa* suggests very strongly that a similar feature occurs in this species, though it is true that Lang appears to regard the pigment patches as merely epidermal.

Mention should be made here of the fact that von Plehn [10] has figured the occurrence of marginal pores opening from the gut in an undescribed Planoceroid. In the species described next the large spherical bodies of the gut epithelium are present, but there are no diverticula and neither of the other kinds of dark bodies.

Genital apparatus. The characters are shown somewhat diagrammatically in Pl. XV. fig. 11. In the female system the accessory vesicle (*a. v.*) of the vagina is thread-like and extends back as far as the level of the female aperture (♀). After receiving on its ventral side the common duct from the two uteri (*c. d.*), the vagus (*va.*) follows a winding course through the enormous shell glands (*s. g.*), and runs into a large bursa copulatrix (*b. c.*), whose lumen has many folded walls, appearing in part at any rate to be glandular. As in other typical members of the genus the terminal parts of the male apparatus are enclosed in an outer muscular sheath (*o. s.*), in which lie the penis and the prostate (*pr.*) as well as the duct. A remarkable feature of the penis, and one that separates this species sharply from other known *Planocera*, is the presence at the end of that organ of six large chitinous hooks (*c. h.*) and at its upper end of a chitinous ring or collar (*c. r.*). The lumen of the penis is lined by a very large number of small chitinous spines (*c. s.*). These vary from ·05 to ·07 mm. in length. The space between the penis and outer sheath is occupied by a very loose parenchymatous tissue.

Female organs. At its hinder end the accessory vesicle (*a. v.*) is difficult to trace owing to its extremely small size. The lining cells are not ciliated. As it passes forward it increases in size and a very few circular muscles appear about it. After receiving the short common duct (*c. d.*) from the uteri, which are also lined with non-ciliated epithelium, the vagina (*va.*), as it must now be called, continues to run forwards for some little distance. It then turns first ventralwards and then backwards. As it turns back it widens out so that its lumen is wide from side to side but narrow dorso-ventrally. In this part of its course it receives the secretion of the relatively enormous shell-glands (*s. g.*), which have a characteristic granular appearance and stain very lightly. The vagina continues to run backwards, passing right through the shell-glands until it lies right under the front end of the bursa. Here its lumen becomes circular in section. It now makes a Z-shaped turn upwards, and runs into the hinder end of the large bursa copulatrix (*b. c.*). As the vagina passes into the bursa its lining epithelium undergoes a marked change. Up to this point it consists of a fairly well-defined, cubical epithelium with deeply staining nuclei, apparently non-ciliated. As it passes into the bursa it becomes irregular and much folded; the protoplasm stains more deeply, and the nuclei can with difficulty be distinguished. From its proximal, anterior end the epithelium lining the bursa (*g. l.*) retains these characters almost to the gonopore, in the neighbourhood of which it merges into a columnar non-ciliated epithelium, continuous with the epithelium of the surface. The epithelium of the bursa is secreting very actively a remarkable 'glairy' substance, which occupies nearly the whole lumen of the bursa. Outside this epithelium the bursa is built up of a thick muscle layer of circular fibres. The folding of the wall lining the lumen of the bursa is no doubt, as Lang suggests, to permit of the distension of the organ. The secretory character of its wall is, so far as is known, confined to this species, and without homologue in the bursa of any Polyclad I am acquainted with. This peculiarity combined with the very remarkable nature of the penis indicates that this species is one of the most specialized in the whole order.

Male apparatus. The gonopore opens into an antrum masculinum whose walls closely resemble those figured by von Graff for his *Pl. simrothi* [6]. Little spherical masses of granular secretion given off from the cells lining the antrum lie scattered in its cavity. The outer sheath (Pl. XV. fig. 12, *o. s.*) is composed of two layers of muscle fibres, an outer longitudinal

and an inner circular layer. At its anterior proximal end it is pierced by the ductus ejaculatorius running into it from the small muscular vesicula seminalis (*v. s.*). At the same end lies the large prostate gland (*pr.*), whose duct joins the ductus ejaculatorius some way before entering the penis. Retractor muscles run from the upper end of the penis, and from the distal part of the ductus to join the outer sheath.

A transverse section through the distal lower limit of the penis is represented somewhat diagrammatically in fig. 13. The irregular lumen is seen to be lined with short chitinous spines (*c. s.*) and the section passes through the bases of the six large hook-like structures (*c. h.*). Outside the spines and hooks is a narrow layer of hyaline protoplasm, and beyond this the irregular, diagonal, intrinsic muscles of the penis (*p. m.*) in close contact with the muscles of the outer sheath, here rather feebly developed. The small cavities (*a. m.*) are parts of the antrum masculinum. The irregularity of the lumen is probably due to shrinkage. Further forward a transverse section shows the hyaline layer rather more clearly defined, and outside it is a broad muscle layer composed of diagonal fibres which are closely packed together on the inside, but loosely arranged to the outside, so that no very clear boundary can be distinguished between the muscles and the parenchyma, which have divided the intrinsic muscles of the penis from those of the outer sheath.

At the level of the chitinous 'collar-like' structure the sections have unavoidably been torn. Consequently I cannot be certain of the relationship of the collar to the penis or to the retractor muscles, but some of the latter seem to be attached to it. The collar itself, seen in the animal when cleared in oil of cloves before it was cut into sections, appeared as a ring of chitinous material, its upper, anterior end wider than the lower, and its outer surface decorated with a rectangular sculpturing. On account of the tearing of the sections it is also impossible to say whether the ductus ejaculatorius entered the penis by passing through the collar or to the outside of it.

In a transverse section in front of the penis but before the level of the prostate, the ductus ejaculatorius can be seen running through the middle of the section. It has a narrow lumen lined with ciliated epithelium. Outside this is a thin layer of circular muscle fibres followed by a longitudinal layer. From this longitudinal layer a number of bundles of retractor muscles are given off, exactly similar to those connected with the hinder end of the penis itself. In sections at this level many of them lie cut across obliquely amongst the parenchyma which here fills the wide space between the ductus and the outer sheath. The ductus runs nearly straight back to the prostate. Just before entering the latter it divides into a wider part running to the gland and a narrower part continuing to the vesicula seminalis, after piercing the wall of the outer sheath. It is interesting to find here a little peculiarity which evidently also occurs in *Pl. pellucida* (see von Graff's figure [6]), *i.e.* the duct from the vesicula does not open immediately into that from the prostate, but is actually prolonged for a short distance inside it. This prolongation is probably of the nature of a valve. Each of these two parts making up the ductus ejaculatorius is provided only with circular muscle fibres; but, whereas those of the prostatic part are few in number, those of the part running to the vesicula though few at first increase rapidly in number as the vesicula is approached.

The prostate (*pr.*) is a large gland, lying in close contact with the outer sheath at its anterior end; in fact the circular muscles of the sheath completely enfold it, and form a muscular wall for it. On the inside it is lined with a much-folded glandular epithelium. The vesicula

seminalis lies outside the outer sheath. It is small, with thick muscular walls composed of circular fibres. The vasa deferentia before joining it are much swollen and full of spermatozoa; they are lined with a cubical ciliated epithelium, and have no nuclei. The vesicula itself contains no spermatozoa.

2. *Planocera langii*, sp. n. (Pl. XIV. fig. 1, and Pl. XV. fig. 13).

One specimen from Minikoi. "White transparent form." Body flat, oval; margin folded.

Total length about 20 mm. Front margin to mouth opening 11 mm. Front margin to male aperture 13·5 mm. Male to female aperture about ·3 mm. Tentacles about 7 mm. from the anterior margin, and about 1·5 mm. apart.

Tentacular eyes numerous, small, lying at the base of either tentacle in a dense cluster. Tentacles slightly bilobed at their ends. Behind the tentacles is a single pair of small eyes, lying over the brain. Colour white, with a few small black chromatophores lying scattered round the pharynx region dorsally. There are in addition a number of exceedingly small black spots consisting apparently of pigment granules visible on the dorsal surface above the hinder part of the pharynx. These granules lie in the parenchyma, and are not of course comparable in any way to the diverticula described in the previous species. Similar granules occur in an undescribed species of *Planocera* from Rotuma.

Genital apparatus. An examination of the accompanying Figure 62 shows that the present species differs strikingly so far as these organs are concerned from *Pl. armata*. In fact it seems impossible to homologize the bursa copulatrix of the one with that of the other. The female aperture (♀) leads into a spacious antrum femininum into which the shell-glands (*sh. gl.*) open. From the antrum a short passage runs dorsalwards. It quickly divides to form the vagina which runs backwards, and the bursa copulatrix (*b. c.*) which extends forwards alongside the penis, lying at rather a higher level than the vagina (see fig. 13). The latter after a short distance bends ventralwards, and at the same time receives the separate openings of the uteri (*ut.*). Beyond this the character of its lining epithelium alters completely, and the organ is continued backwards as an elongated vesicle, which may be called the receptaculum seminis (*r. s.*), homologous with the accessory vesicle of *Pl. armata*. A remarkable feature of the male apparatus is the presence of a pair of vesiculae seminales, dilations of the terminal parts of the vasa deferentia with thick muscular walls. Compared with *Pl. armata*, this species has a long 'outer sheath' with feeble walls. The penis is long and twisted, without retractor muscles. The chitinous spines lining its lumen are relatively few, and there are neither chitinous hooks nor ring. The penis extends right back to the level of the prostate, which communicates with it by a short wide duct.

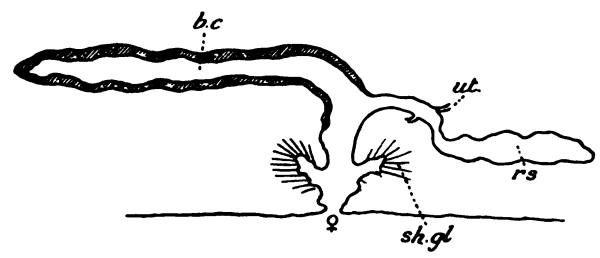


FIG. 62. Female apparatus of *Planocera langii* (diagrammatic). For explanation of lettering see text.

Female organs. The receptaculum seminis (= accessory vesicle) is lined by a regular, columnar, ciliated epithelium, resting on a fine, basal membrane. All the nuclei lie at the lower extremity of their cells, close to the membrane. They have a lightly staining ground-substance with scattered chromatin granules. The protoplasm is faintly granular. The receptaculum lies

rather near the ventral surface. As it approaches the vagina it makes a sharp turn up and the appearance of the epithelium changes; circular muscle fibres make their appearance, and, after receiving the uterine openings, the organ is continued forward as the vagina, the epithelium here consisting of a short, columnar, ciliated facies. The nuclei are homogeneous and darkly-staining; the protoplasm is hyaline. The bursa copulatrix extends forward as far as the front end of the male apparatus. Its inner walls are much folded and lined with cubical non-ciliated epithelium. Outside this it has moderately thick muscular walls composed of circular fibres. The undescribed species from Rotuma, to which I have already referred, bears a strong resemblance so far as the female apparatus is concerned to *Pl. langii*. In it the receptaculum seminis is crowded with spermatozoa.

Male apparatus. The outer sheath consists in this species of circular fibres only. From the antrum masculinum for about a quarter of its length, which is roughly a millimetre, it is continuous with the intrinsic muscular wall of the penis, and traversed by scattered, radial fibres running from the latter.

After this a split appears between it and the intrinsic muscles of the penis, leaving a space round the latter. At the upper anterior end the prostate as in the other *Planocera* lies in close contact with the outer sheath. The few muscle-fibres surrounding the prostate do not seem to be derived from the outer sheath. Lastly the sheath is pierced at two points by the ducts running to the penis from the vesiculae seminales.

The penis is approximately a millimetre in length. It is a cylindrical, tube-like organ, its lumen lined with chitinous spines, which are a little hooked and not very thickly set. The diameter is roughly equal throughout its entire length. The muscular wall consists of a well-defined, rather thick layer of circular fibres crossed by radial fibres. The penis is continued right up to the level of the prostate, which communicates with it by a short, wide, muscular duct, opening into it at the same point as do the ducts from the vesiculae.

At a point about one-third of the total length of the penis from the male aperture the chitinous spines are interrupted by the appearance of two curious folds of the inner wall (Pl. XV. Fig. 13, *pl.*). These folds are margined with chitinous material. It is possible that they may be to some extent comparable to the chitinous hooks or collar of *Pl. armata*, but their function is quite unknown to me. Behind them the spines are continued again up to the level of the opening of the prostate duct. As already stated each of the vasa deferentia is dilated before entering the outer sheath to form a vesicula seminalis, and the dilated part has muscular walls composed of circular fibres. The ducts running from the vesiculae to the penis are also muscular.

Before passing to consider the species belonging to the next family I may briefly notice the presence of a large Planoceroid represented by a single damaged specimen in the collection, which I am not able to describe. Its total length is probably about 45 mm. A pair of dorsal tentacles are visible. It is perhaps a *Stylochoplana*. I could only find indications of a single genital aperture, the genital organs being quite immature.

II. Family Leptoplanidae.

3. *Leptoplana pardalis*, sp. n. (Pl. XIV. fig. 9, and Pl. XV. fig. 14).

Several specimens from the reef, Goidu, Goifurfehendu Atoll, and from Minikoi, Laccadive Group.

Average length about 48 mm. Eyes distant 10 mm. from the anterior margin. Mouth opening about 20 mm. from the anterior margin. The male aperture lies about a millimetre in front of the female, the latter is about 15 mm. from the hinder end of the body.

The colour (in spirit specimens) is pale yellow. On the dorsal surface this is thickly studded with rosette-like clusters of brownish-black chromatophores. On the mid-dorsal line in the middle third of the back these chromatophores form a continuous band; near the margin the clusters are replaced to some extent by single chromatophores.

The eyes are arranged in two clusters of 'tentacle-eyes' of moderate size, each containing about a score of eyes. In front of them lie on either side about as many more eyes scattered irregularly. The gut branches anastomose.

This interesting species combines to some extent the characters of *Discocelis* with those of *Leptoplana*. The presence of a pair of receptacula seminis developed from the accessory vesicle of the vagina resembles the condition found in *Discocelis tigrina*, whilst the absence of marginal eyes and the widely separated gonopores forbid us to refer it to that genus. On the whole it is most conveniently placed in the genus *Leptoplana* as at present constituted, the male organs resembling those of other species of that genus.

Female apparatus. (See Figure 63.) The vagina (*va.*) runs back from the female aperture (♀) and receives the common duct (*c.d.*) from the uteri.

These latter extend forward from the short common duct, each being formed of two distinct sections. Firstly there is a duct-like part, consisting of a narrow tube lined with cubical, ciliated epithelium, surrounded by a few circular muscles (*u. d.*). This opens at about the level of the male aperture into a wide, irregular, glandular part, the pair extending forward on either side of the pharynx, and in one of the specimens, examined by sections, containing eggs. The walls of this glandular part (*u. gl.*) are much folded, and their epithelium is secreting actively and full of globules of a finely granular substance. Cell outlines are not visible.

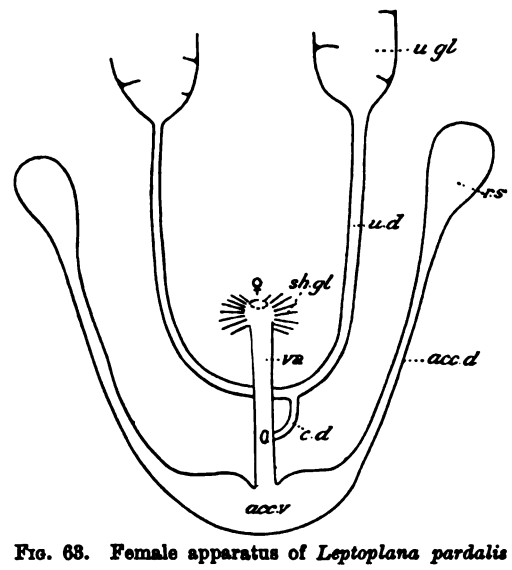


Fig. 63. Female apparatus of *Leptoplana pardalis* (diagrammatic). For explanation of lettering see text.

Behind the entrance of the common duct from the uteri the vagina, whose lumen is lined by cubical, ciliated epithelium surrounded by circular muscle fibres, runs back for a short distance, and finally opens into a crescentic accessory vesicle (*acc. v.*) with its horns directed forward. From either horn a narrow duct (*acc. d.*) runs forward, ending in a spherical dilatation (*r. s.*) which probably functions as a receptaculum seminis. The cubical epithelium, lining the accessory vesicle and the ducts opening into it, is not ciliated. In one specimen the receptacula are crowded with spermatozoa, surrounding a mass of what appears to be a granular secretion.

Considerable interest attaches to this species in that the walls of part of the uteri themselves are glandular. Glands in connection with the uteri are as a rule only present in certain Cotylea, such as *Diposthus*, *Pericelis* and various Euryleptidae, where they occur in

diverticula from the uterus. The accessory vesicle on the other hand only occurs in the Acotylea. In *Discocelis* it is glandular.

Male apparatus. The vasa deferentia dilate at their terminations to form a pair of moderately wide vesiculae seminales whose walls are surrounded by a thin layer of circular muscle-fibres. These vesiculae open into a short and narrow ductus ejaculatorius (Pl. XV. fig. 14, *d.e.*) lined with ciliated epithelium and provided with rather thick muscular walls. This duct narrows suddenly as it enters the muscular penis (*pe.*), which projects as a bluntly conical muscular mass into the antrum (*a.m.*). The antrum is lined with non-ciliated epithelium and its walls are muscular, forming the muscle sheath; I can find no trace of gland-cells in the epithelium.

Amongst the six specimens of this species collected at Minikoi is one which differs from the rest in coloration, being much darker. After a careful examination I have come to the conclusion that this difference is chiefly due to the expanded condition of its chromatophores, though they may be slightly more numerous. Unfortunately it is not possible to say whether this specimen was collected under different conditions from the others. Since examining these specimens I have received from Mr Gardiner three others, which I believe to be specifically identical with them, from Funafuti in the Pacific.

4. *Leptoplana*, sp.

One specimen from Minikoi. Damaged.

The arrangement of the eye-spots is that of a typical *Leptoplana*. There are a pair of small compact 'tentacle-eye'-groups, and in front of these the scattered brain-eyes.

Genital apparatus. The female aperture lies about two mm. behind the male, unfortunately the hinder part of the female apparatus is missing, but it bears a fairly close resemblance so far as can be determined to that of *L. vitrea* as figured by Lang. The shell-glands are very numerous, their secretion takes the form of enormous numbers of minute rhabdite-like bodies, similar to those found in *Pericelis* (see below). These rhabdites can be seen making their way into the lumen of the vagina. In the neighbourhood of the terminal parts of the genital apparatus the unripe shell-glands are so numerous as to give the tissue a characteristic appearance. They resemble closely those of *L. alcinoi* figured by Lang ([9] T. 14, Fig. 2), but in the latter species they are pyriform, whilst in the species under consideration they are spherical.

As they ripen and become filled with the small rhabdite-like bodies, the cell outlines become obscured, and finally the cells seem to disappear as though they had ruptured to permit of the escape of the contained rhabdites.

The walls of the vagina are lined with ciliated epithelium, and, as it passes back from the antrum, a fairly strong muscle layer developes about it. After running for a short distance backwards the vagina turns upwards and a little forwards and then finally backwards, receiving the separate openings of the uteri. Thence it continues back, first as a narrow tube, but further back appearing to open into a wide accessory vesicle; owing to the displacement of the organs at the hinder end of the body it is extremely difficult to follow. The uteri run forward, and for the first millimetre or so of their length have muscular walls, further on the muscles disappearing.

In the male apparatus the vasa deferentia open into a muscular vesicula seminalis, resembling in shape that of *L. vitrea*. From the front end of the vesicula the ductus ejaculatorius runs backwards and downwards for some distance; its lumen is rather wide and it is lined with glandular prostatic cells, outside which lies a layer of circular muscular fibres. This part of the apparatus resembles rather that of *L. pallida* than of *L. vitrea*. The rest of its structure is practically identical with that of *L. vitrea*. The duct narrows, and runs vertically upwards, then turns downwards and backwards again, extending parallel to the first part of its downward course. It is here very narrow, surrounded by a compact layer of circular fibres, outside which lie less compact, diagonal fibres. It opens finally into the antrum masculinum. These muscles form the penis.

As this specimen is in an imperfect condition I cannot describe it fully, though I believe it to be quite distinct from any named species.

III. Family CESTOPLANIDAE.

5. *Cestoplana ? maldivensis*, sp. n.

A single specimen from the reef of Minikoi, Laccadive group.

Total length about 15 mm., breadth 5 mm. Body flat, anterior end pointed, posterior end tapering a little. Colour (in spirit specimen) uniform dull brown. The hinder end of the body of the single specimen has unfortunately been so much damaged that it is impossible to determine the characters of the sexual organs.

The pharynx has the position typical for *Cestoplana*, and the mouth opening is about 4 mm. from the hinder end, whilst the male aperture is certainly not more than 2 mm. from the extremity.

From the two species of the genus previously known, viz. *C. rubrocincta* (Grube) and *C. faraglionensis* (Lang), the present species is separated by its relatively short and wide body. Another more striking difference is afforded by the arrangement of the eye-spots. In *C. maldivensis* there is a complete series of these round the margin of the body (see Fig. 64), on the posterior two-thirds of the body being few and distant, but on the anterior margin on either side as far back as the level of the brain thickly scattered. In addition to these in the apex of the triangular anterior end of the body lie a small number of eyes scattered over an area which stretches back for about half the distance from the apex to the brain; and further from the middle of the hinder end of this area two irregular parallel lines, each of a single row of eyes, extend back as far as the brain, which lies at about the end of the first sixth of the body.

The uteri can be traced forward through the hinder two-thirds of the body, and are crowded with eggs. Until it is possible to examine the genital apparatus of this species in a better-preserved specimen I prefer to leave it in the genus *Cestoplana*, although there can be no doubt that it differs strikingly from typical members of that genus.

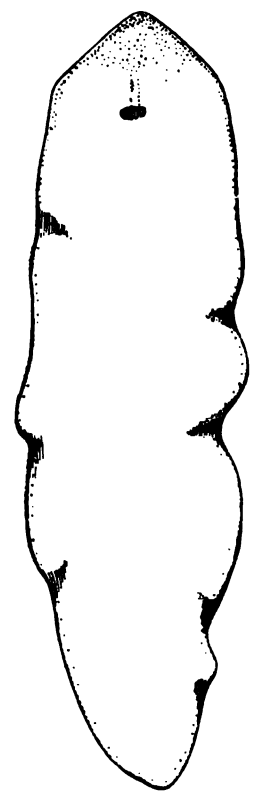


FIG. 64. *Cestoplana* (?) *maldivensis*. × 7.

COTYLEA. IV. Family PERICELIDAE, nov.

6. *Pericelis byerleyana* (Coll.) (Pl. XIV. fig. 6, & Pl. XV. fig. 15, 16, & 17).

Typhlolepta byerleyana. Collingwood, Trans. Linn. Soc. Lond. (2) i. p. 92; Lang, Naples Monogr. p. 616.

Five specimens from Minikoi.

Collingwood's description of this species is as follows:—"Length $\frac{3}{4}$ inch, breadth $\frac{3}{8}$ inch. Body smooth, thin, the lateral parts very ample and puckered. Upper surface beautifully marbled with light brown rings, including roundish spaces of a whitish colour, smaller rings being between the interstices of the larger; most crowded and darkest in colour along the median line, and more delicate towards the side. Under surface of a pale grey, the dendritic markings in the centre of an opaque white. Its movements were very contorted and it did not exhibit much activity. One specimen from under a piece of coral on Pulo Barundum off the west coast of Borneo."

In Mr Gardiner's collection are five specimens agreeing with this description so far as it goes, save that three of them are of considerably greater size. They are however provided with tentacles on the anterior margin, and with eyes; but I believe that Dr Collingwood may well have overlooked these owing to the extreme folding of the edge of the body.

Owing to the fact that this species possesses both eyes and tentacles it must be removed from the genus *Typhlolepta.* Its characters, moreover, are such as to distinguish it from all other Cotylea sufficiently to make it the type of a new genus and family[1].

The family *Pericelidae* may be defined as follows:—"Cotylea with small widely separated tentacles, with a complete series of marginal eyes; penis single; pharynx central; margin of the body excessively folded." Genus *Pericelis.*

The nearest ally of this interesting form is, I consider, *Anonymus,* the only other Cotylean Polyclad in which there is a complete series of marginal eyes. *Pericelis* further has the anterior margin notched in the middle line just as in *Anonymus.*

The most striking feature of the species, when viewed with the naked eye, is the extreme folding of the margin of the body. In one of the larger specimens the length of the body along the middle line is 35 mm., and the breadth at its middle about 32 mm., whilst the 'rim' of the body when spread out is not less than 230 mm. in length. In this same specimen the small tentacles lie not less than 9 mm. apart. They are crowded with eyes, and eyes are scattered completely round the margin inwards for a depth of about 5 mm. In the middle of the anterior margin is a well-marked notch or indentation, about 5 mm. behind this in the middle line is the elongated cluster of brain-eyes.

Other measurements are as follows:—mouth opening about 18 mm. behind the anterior margin. The male gonopore lies about 4 mm. behind the mouth. The female gonopore about 2·5 mm. behind the male. Sucker 1 mm. behind the female orifice.

To Collingwood's account of the coloration nothing need be added. I have ventured to give a coloured figure of one of Mr Gardiner's specimens to show the position of the tentacles and brain-eyes. It illustrates too the extraordinary amplification of the lateral parts of the body.

[1] The species is evidently a widely distributed one. I have received recently a sixth specimen of it from Mr Gardiner from Rotuma in the Pacific.

approximate more closely to the yolk-glands of the Triclads than to any structure previously known amongst the Polyclads. It is possible, however, that they are connected with the cell-like bodies found in the uterine vesicles as described above.

Male apparatus. The vasa deferentia are crowded with spermatozoa. They enter the walls of the penis some little distance behind its anterior end, narrowing as they do so. For the first third of its length its lumen is lined by glandular cells, and filled with a coarsely granular secretion (see Fig. 66). For the rest of its length it has a cubical ciliated epithelium, as also has the antrum masculinum. The wall of the penis is composed chiefly of circular fibres, interspersed with a few radial. The antrum becomes extremely narrow as it approaches the gonopore, and the latter is correspondingly minute.

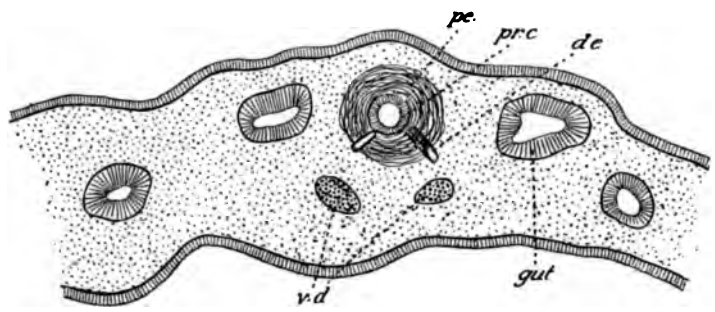


FIG. 66. Section across the base of the penis of *Pericelis byerleyana*.
pe. = penis, *pr. c.* = glandular cells, *v. d.* = vasa deferentia, *d. e.* = vas deferens entering penis.

Leaving the specialized *Prosthiostomum* out of account I believe that all other Cotylea save *Anonymus* have a special muscular prostatic organ connected with the penis by a short duct. Consequently *Pericelis* is more nearly related to *Anonymus* in the structure of the terminal parts of this organ than to the rest of the Cotylea.

V. Family PSEUDOCERIDAE.

7. *Thysanozoon plehni*, sp. n. (Pl. XIV. fig. 7, and Pl. XV. fig. 19).

Three specimens "from the reef-flat" Minikoi, with "brown to slate-black papillae."

Total length about 23 mm. Total breadth about 17 mm. 'Mouth opening' about 5 mm. behind the anterior margin. ♂ aperture 4 mm. behind the 'mouth.' ♀ aperture 1 mm. behind the male. Sucker 2 mm. behind the female aperture.

The ground-colour of the body in the spirit specimen is a dull pale yellow. On the dorsal surface lie a considerable number of black, rather pointed papillae; the small marginal tentacles are also black. Brain-eyes in a single small cluster; tentacle-eyes arranged along the anterior side of the tentacles (Fig. 67).

The muscle-layers of the body-wall are but feebly developed. The dorsal papillae contain no gut diverticula, only a loose parenchyma. Their epithelium is composed of very long, columnar cells, loosely connected with each other, containing clusters of rhabdites which vary in length from ·01 to ·0275 mm. In addition to the rhabdites the epithelium of the papillae secretes a small number of pseudorhabdites, bodies of about the same length as the larger rhabdites, but two or three times as broad and of a finely granular texture. They occur nowhere save on the papillae (Pl. XV. fig. 19). At the tip of each papilla is a small

'plug-like' mass of tissue derived in part from the parenchyma and in part from the epidermis, which differs from the tissue surrounding it in being denser and in staining more deeply. It occurs in every papilla through which my sections pass, but I cannot offer any suggestion as to its significance.

FIG. 67. Tentacles and eyes of *Thysanozoon plehni*.

Behind the level of the pharynx, which resembles that of other species of the genus, the main gut gives off numerous branches. *These do not all arise from it in the same plane*, but at the same time no branches are given off from the ventral side. Von Plehn [10] in describing two new species, which she calls *Thysanoplana indica* and *Thysanoplana marginata*, pointed out that a similar peculiarity occurs in those species, but to a much greater extent, for in them apparently the branches may in addition originate from the ventral side of the main gut. I have also found—from a careful examination of a series of sections in the Laboratory Cabinet of the Owens College Zoological Department—that in the neighbourhood of the male aperture of *Thysanozoon brocchii*, and for some little distance behind it, the gut branches do not all rise in exactly the same plane, though only from the lateral walls of the main gut. It is in the same neighbourhood, viz. in that part of the body where the main gut is largest, that this feature is most marked in von Plehn's species of *Thysanoplana* as well as in *Thysanozoon plehni*.

Genital organs. Excepting in detail these resemble very closely those of other species of the genus, and especially those of *Th. auropunctatus* (Coll.) as figured by von Stummer-Traunfels [14]. The terminal parts of the female ducts are in no way peculiar. The eggs, like those of other species of the genus, exhibit large centrosoma.

Male apparatus. The vasa deferentia unite to enter the vesicula seminalis by a short common duct ("gemeinschaftlicher Einmündungsgang" of von Stummer-Traunfels), which runs dorsalwards to open into the lower side of the vesicula near its hinder end. The vesicula extends forwards and a little downwards for the greater part of its length, but close to its anterior end it curves suddenly downwards and narrows into the duct to the penis. This duct is long, more than twice the length of the vesicula, and after a tortuous course enters the base of the penis, where it is joined by a very short duct running from the small prostate gland, which lies close above and behind the penis. It is lined with secretory epithelium, and has a compact muscular wall composed of diagonal fibres. The penis is armed with a short tubular chitinous stylet and projects into a cavity, whose walls form the penis-sheath. This cavity opens immediately below the penis into the antrum masculinum, which in turn opens to the exterior by the male gonopore.

It is of some interest to find that, whereas the gonopore is situated on the middle line, the penis with the penis-sheath lies very decidedly to one side of it, the right side. But the cavity of the antrum is extended fairly equally both to the right and to the left of the middle line. This peculiarity perhaps indicates that this species is descended from a form in which, as in many other species of *Thysanozoon*, the penis is paired, and that one of the pair, the left in this instance, has disappeared leaving the right penis to open unsymmetrically into the symmetrical antrum. In Lang's Monograph, T. 30, fig. 17, a diagrammatic figure is given of the terminal male apparatus of *Pseudoceros maximus*—a species belonging to a closely-allied genus—which possesses a pair of penes. If we picture one of these penes to be atrophied, the diagram would represent very closely the appearance seen in a section of the present species passing through the penis and antrum masculinum.

Thysanozoon plehni is on the whole most closely related to *Th. obscurum* described by von Stummer-Traunfels [14] from Amboina.

Genus *Pseudoceros.*

A. Forms with a pair of penes.

8. *Pseudoceros gardineri* sp. n. (Pl. XIV. fig. 4).

One specimen from Hulule, Male Atoll.

Total length about 35 mm., total breadth about 22 mm. Mouth opening 8 mm. behind the anterior margin. Female gonopore about 5 mm. behind the mouth. Sucker 7 mm. behind the female gonopore.

The margin is much folded. Body flat, oval with a prominent mid-dorsal longitudinal ridge. Colour: dorsal surface a delicate gray with scattered irregular black marks of varying size dotted over the surface; under surface grayish-white.

The marginal tentacles are sharply pointed, large and prominent. The eyes, which are exceedingly numerous, are grouped as follows. A large compact cluster containing about 200 eye-spots lies over the brain. This is circular in shape save for a slight notch in the middle of its hind margin. On the dorsal surface of either tentacle near the middle line and close to the anterior margin is a group of eyes, rather more scattered than those of the brain-cluster. On the outer side of each of these clusters is a second still more diffuse group. On the ventral surface of the tentacles, almost immediately under the more medially placed dorsal group, are two roughly square compact patches; from the outer side of each of these a small 'wing' runs on to the ventral side of the tentacles (Fig. 68). The projecting 'wing' is concealed by marginal folds.

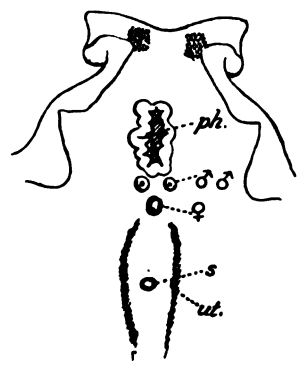


FIG. 68. Ventral surface of *Pseudoceros gardineri.* *ph.* = pharynx, *s.* = sucker, *ut.* = uterus, ♂ ♂ = penes, ♀ = female aperture.

9. *Pseudoceros punctatus* sp. n. (Pl. XIV. fig. 5).

One specimen from Hulule, Male Atoll.

Total length about 30 mm., breadth about 17 mm. Mouth about 5 mm. from anterior margin. Female gonopore 4 mm. behind mouth. Sucker 4 mm. behind female gonopore.

Body oval, flat, with well-marked, median, longitudinal ridge. Colour pale grayish-yellow, plentifully spotted on the dorsal surface with small black chromatophores.

The tentacles are pointed as in the preceding species.

The eyes over the brain form a very small cluster of some 25—34 minute eyes. At the base of each tentacle, on the dorsal side and close to the anterior margin, is a small, ill-defined cluster of eyes, and there are also a few scattered eyes on the outer sides of the tentacles. On the ventral side of the tentacles are a pair of small clusters near the middle line and a few scattered eye-spots along the tentacle fold.

The species is readily distinguished from the preceding by its possessing much more distinctly defined and more regular chromatophores, as well as by the relative fewness of its eyes. It yet resembles it especially in the shape of the tentacles, which are more like those found in certain Euryleptidae than those of most Pseudoceridae.

B. Forms with a single penis.

10. *Pseudoceros gamblei* sp. n. (Pl. XV. fig. 18).

Several specimens from Minikoi, Laccadive Group, 'milk-white' or 'transparent flesh colour' with purple or dark-blue rims.

Total length about 12 mm., breadth 6 mm. Mouth opening about 2 mm. behind the anterior margin. Female aperture about 1 mm. behind mouth. Sucker about 1 mm. behind the female aperture.

A small circular cluster of eye-spots lies over the brain about 1·2 mm. behind the anterior margin. There is a row of eyes along the margin of the tentacles both on the dorsal and ventral sides, which is continuous across the middle line (Fig. 69).

Sections were cut transversely through the anterior region of the body of a semi-adult specimen. Rhabdites appear to be absent in the epithelium, and the muscle layers of the body-wall are feebly developed. The testes lie, as is usually the case, on the ventral side of the gut, and the ovaries which are immature can be recognised on the dorsal side. The penis is that of a typical Pseudoceroid. The vasa deferentia before uniting to form the muscular ductus ejaculatorius are each dilated to form a vesicula, which is crowded with spermatozoa (Pl. XV. fig. 18).

A feature of the species is the curious shape of the pharynx, which has its hindmost folds produced backwards to form wing-like projections on either side, extending as far back as the level of the female aperture (Fig. 69).

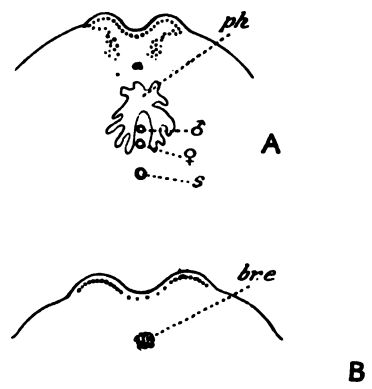


FIG. 69. Anterior end of *Pseudoceros gamblei*. A. from ventral; B. from the dorsal side.
ph. = pharynx, *br.e.* = 'brain-eyes,' *s.* = sucker, ♂ = penis, ♀ = female aperture.

11. *Pseudoceros tigrinus* sp. n. (Pl. XIV. fig. 3).

One specimen from Minikoi, Laccadive Group.

Total length about 17 mm., breadth 11 mm. Mouth aperture about 4 mm. from anterior margin. Male aperture about 5 mm. from anterior margin. Sucker about 3 mm. from male aperture.

Ground colour orange-pink, margin and tentacles black.

On the dorsal side, on either side of the middle line a black band runs from the anterior margin to within a short distance of the posterior margin. These two bands meet each other across the middle line at their anterior and posterior extremities. In addition to these black, triangular patches project inwards at intervals along the margin; these like the two median bands have on them a few rather large, circular, pink spots, and between these the black is thickly flecked with very small white spots.

The position of the eye-spots is completely concealed by the pigmentation of the body, which readily serves to distinguish the species.

The remaining specimens referable to this genus, some eighteen in number, are all very similar to one another in appearance, being of black colour with yellow margins. Two distinct

forms can be recognised. The first of these has a narrow pale yellow border and its ground colour is a greenish-black. The second has a broader orange border and its ground colour is rather a velvety-black.

Excepting for the above difference it is difficult to find any distinguishing characters. Measurements are of little value owing to the varying degrees of contraction of the several specimens, and the dense pigmentation makes it impossible to determine the arrangement of the eye-spots, especially those of the tentacles, with any degree of accuracy.

I believe the form with the pale narrow yellow margin is identical with *Proceros buskii* of Collingwood, found by him in Singapore Harbour. In his description [4] he gives the colour of the body as a rich velvety olive-green, but in his figure the body is shown rather as black. The appearance of the margin in his figure of *Proceros buskii* agrees with that of my specimens. I feel therefore justified in identifying them with Collingwood's species.

12. *Pseudoceros buskii* (Collingwood).

Proceros buskii Collingwood [4], p. 91, Pl. I. fig. VI.

Pseudoceros buskii Lang. Naples Monogr. p. 547.

Ten specimens from Hulule and Minikoi.

Length about 22 mm. Breadth about 12 mm. Mouth opening 5 mm. behind anterior margin. Sucker 8 mm. behind mouth.

Colour black or greenish-black with a narrow pale-yellow margin. Eyes on the tentacles and in a small cluster over the brain; only visible in sections.

The other eight specimens which have a broad orange margin are I think allied to *P. buskii* on the one hand and on the other to *P. velutinus* Lang, a species recorded from Ceylon. I think it advisable to refer them for the present at any rate to a new species under the name of *Pseudoceros flavomarginatus*.

13. *Pseudoceros flavomarginatus* n. sp.

Eight specimens from Minikoi, Laccadive Group.

Length about 25 mm. Breadth about 15 mm. Mouth aperture about 5 mm. behind the anterior margin. Sucker about 7 mm. behind the mouth.

Colour velvety-black with an orange margin about 1·5 mm. wide.

Eye-spots occur on the tentacles and over the brain.

It will be noticed that this species is a little longer than *P. buskii* and that perhaps the relative position of certain organs is different. But, as already remarked, much importance cannot be attached to measurements.

VI. Family Prosthiostomidae.

14. *Prosthiostomum elegans* sp. n. (Pl. XIV. fig. 8, Pl. XV. fig. 20).

A single specimen, dredged off hard sand, at 30 fathoms, in the lagoon of Suvadiva Atoll.

Length of body about 18 mm., breadth 4·5 mm. Anterior margin rounded, posterior end of the body pointed.

Colour, in the spirit-specimen, pale primrose-yellow. From immediately behind the level of the brain, on either side of the longitudinal mid-dorsal ridge, extends a row of chocolate-

brown chromatophores, about 12 in each row. In addition to these there is a single small chromatophore on either side of the brain (see Pl. XIV. fig. 8). Under surface entirely primrose-yellow.

A number of minute eyes are scattered round the anterior margin of the body. There are also two groups lying over the brain. These form a V-shaped cluster; the apex of the V is directed forwards, and each of its limbs, narrowing from behind forwards, is made up of some 15 eye-spots, which are rather larger than those of the margin[1].

The margin is not folded. In shape this species approaches *P. dohrni*, Lang, and its structure is closely similar to that of *P. siphunculus* (Delle Chiaji), fully described by Lang. It differs however sufficiently from both and from other species admitted by Lang in colour and in details of the arrangement of the eyes.

It was necessary to examine the specimen by serial sections. I append some details of its anatomy:—

Body-wall. The epidermis consists of a columnar ciliated epithelium, containing but few rhabdites. It rests on a moderately thick basal membrane. The musculature of the body-wall is more strongly developed on the ventral than on the dorsal side. Immediately within the basal membrane lies a thin layer of longitudinal muscle-fibres, next to these circular fibres followed by diagonal fibres. Lastly, on the ventral side only is an inner longitudinal layer.

Pharynx. The pharynx is of course tubular as throughout the family. My sections were only cut a little further forward than the proximal end of the pharynx, and at this end its lumen is triradiate in transverse section (Fig. 70, *A*). This triradial appearance occurs in other species of the genus). It shows some differences in detail from the proboscis of *P. siphunculus* described by Lang [9].

The outer and inner walls are lined with extremely flattened pharyngeal epithelium (Fig. 70, *B*, *o.e.* and *i.e.*). A large number of radial fibres (*ra.m.*) extend right across the wall from

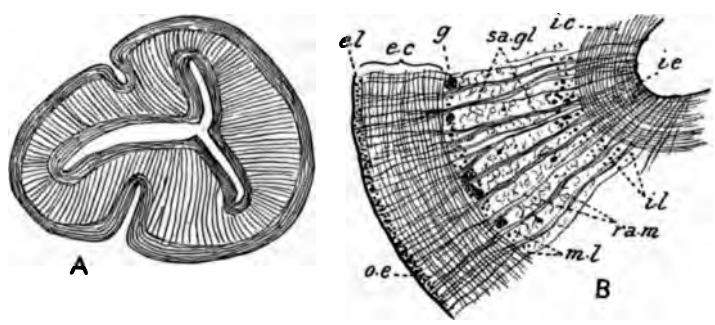


FIG. 70. Transverse section through the pharynx of *Prosthiostomum elegans*.
A. An entire section showing the triradiate lumen. B. Part of the same more highly magnified.
For explanation of lettering see text.

the inner to the outer epithelium. Immediately within the outer epithelium (*o.e.*) is a narrow layer of longitudinal muscle-fibres (*e.l.*), succeeded by a much wider circular layer (*e.c.*). In *P. siphunculus* this circular layer is succeeded by a longitudinal layer, which Lang calls the retractor muscle layer. This layer is present in *P. elegans*, but is only poorly developed (*m.l.*). Amongst the fibres composing it occur a certain number of ganglion cells (*g.*). Below

[1] In fig. 8 the marginal eyes are drawn proportionately too large.

the inner pharyngeal epithelium (*i. e.*) is a thick inner circular muscle layer (*i. c.*) followed by a narrower inner longitudinal layer (*i. l.*). Between this latter and the median longitudinal, or retractor muscle layer (*m. l.*) lie the salivary glands (*sa. gl.*), occupying fully one-half the width of the proboscis. Whilst passing through these the radial muscle-fibres are gathered up into more or less compact bundles.

Gut. The gut-diverticula are precisely similar in structure and arrangement to those of *P. siphunculus*. Their walls are crowded with exceedingly minute bacteria-like structures, which are entirely absent from other parts of the body. In the main-gut, however, I have found what appears to be a distinct kind of bacterial organism in various stages of growth (Fig. 71). The smallest, presumably the youngest stages, are rod-like; as the organism increases in size it gradually acquires a dumb-bell appearance, until finally it consists of two nearly equal sub-spherical masses united by a short stalk. Its subsequent fate I have not been able to trace.

FIG. 71. Bacteria-like organism from the gut of *Prosthiostomum elegans*.

Genital apparatus. Of the female organs only the vagina and shell-glands are developed; they are precisely similar to those of *P. siphunculus*, and in fact of most Cotylea. The male organs are in full functional activity. In this species the relative size of the terminal parts of the male apparatus is much greater than in *P. siphunculus*, otherwise they are very similar in the two species.

The two large vasa deferentia run inwards and forwards at their distal ends to open into the vesicula seminalis, a large sac with muscular walls, composed of circular fibres, lined on the inside with a flattened epithelium. The vasa deferentia do not open into the extreme hind end of the vesicula, but pass into its walls on either side a short way in front of its hinder extremity, and then run backwards in its walls for a short distance before opening into it. This arrangement may act as a valve to prevent 'regurgitation' of the sperm, when the vesicula is contracted suddenly. From the anterior end of the vesicle a ductus ejaculatorius runs forward to enter the penis. It is lined on the inside with a flattened non-ciliated epithelium, outside which is a very thin layer of circular fibres.

Immediately in front of the vesicula, lying side by side above the ductus, are two large spherical vesicles with thick muscular walls composed of circular fibres; outside the muscular layer is a sheath of specialized parenchyma, rather denser than the ordinary tissue. These vesicles are called by Lang 'accessory vesicles.' Their lumen, which is fairly spacious, is lined with a flattened epithelium, bearing a few cilia. Each is provided with a short duct —relatively much shorter than in *P. siphunculus*—which runs forwards, twisting greatly as it goes, lying for the most part dorsal to the ductus ejaculatorius. These accessory ducts, as they may be called, differ greatly from the latter. They are in the first place much narrower, they have a relatively thicker outside wall of circular fibres, and the epithelium through which they run is tubular, that is to say the ducts are intracellular. They pierce right through the muscular coats of the accessory vesicles. "Sie sind innen von einem verschwindend niedrigen Plattepithel ausgekleidet, in welchem die Zahl der einzelnen Epithelzellen andeutenden Kerne so gering ist, dass auf einen Querschnitt des Canales nie mehr als ein Kern zu liegen kommt, so dass man hier auch von durchbohrten Zellen sprechen kann." (Lang [9], p. 276.)

The ductus ejaculatorius (which for convenience I will simply call the ductus) as it approaches the base of the penis is joined by the two accessory ducts, which enter its walls and run forward in them for some distance, lying immediately to the outside of the epithelium of

the ductus itself. After entering the penis the two accessory ducts open into the ductus. The penis is curved downwards and a little backwards; it consists essentially of the end of the ductus, protected by a tapering chitinous tube or stylet, with a narrow lumen, projecting into the antrum masculinum. It can be protruded and withdrawn through the male gonopore by the action of muscle-fibres, attached to the base of the chitinous stylet.

The antrum consists of a small dorsal and a much larger ventral chamber separated from each other by a circular fold of its wall. The roof of the dorsal chamber is of course formed by the attachment of the basal part of the penis to the body. Its walls are lined with a flattened non-ciliated (?) epithelium, through which the secretion of a large number of gland-cells is being poured. These gland-cells lie beneath the epithelium, and may collectively be called the prostate glands. The walls of the dorsal chamber form the 'penis-sheath.' The ventral chamber of the prostate is lined with ciliated epithelium continuous with that of the surface of the body. Its walls have a muscular coat, consisting of an inner circular and an outer longitudinal layer of fibres.

The accessory vesicles are both full of the coarsely granular secretion (fig. 20, *s.*) of the gland-cells of the dorsal chamber of the antrum, and the same secretion is present in the accessory ducts. This secretion cannot be the product of the accessory vesicles themselves, and must reach them through their ducts. But it can only enter the ducts by passing from the antrum through the external opening of the penis stylet, and travelling up the penis to the opening of the accessory ducts into the ductus, and then turning down there. This Lang observes can come about in one of two ways. We may suppose that the secretion may be driven up the accessory ducts by contraction of the walls of the antrum, the male aperture and the ductus behind the openings of the accessory ducts being closed; or the secretion may be drawn into the accessory vesicles by a pumping action of the vesicles themselves. The latter is perhaps the more probable method[1].

The species appears to be most closely related to von Plehn's *P. nationalis* from the coast of Labrador [11].

15. *Prosthiostomum cooperi* sp. n. (Pl. XIV. fig. 2).

Two specimens, one semi-adult, the other immature, from Hulule, Male Atoll.

The larger individual is 17 mm. long and about 5·5 mm. broad.

Colour, milky white, margin of the body much folded. The adult has a series of fine black circular markings, arranged roughly in two parallel rows running down the middle of the back, from immediately behind the brain eyes, almost to the end of the body.

The anterior margin is rounded, the posterior pointed. The anterior marginal eyes are numerous and extend back along the margin considerably beyond the level of the brain eyes. These latter are arranged in two long, almost parallel series, which diverge slightly from each other at their ends.

Body-wall much as in *P. elegans*, but the rhabdites are much more numerous.

Genital apparatus. In both specimens the female organs are undeveloped. In the semi-adult the male apparatus is mature, but unfortunately rather displaced owing to the specimen having been damaged.

[1] An examination of Lang's diagram of the genital organs of *Prosthiostomum siphunculus* will enable the foregoing account to be much more easily followed, see Lang [9] T. 30, fig. 20.

The general arrangement of the terminal organs is similar to that in *P. elegans*, and the relative size of the parts is equally great. The vesicula seminalis lies transversely; this is probably owing to displacement. Its lumen, like that of the accessory vesicles, is relatively very small and the walls thick. The vasa deferentia unite before entering the vesicula, which lies transversely in the body possibly owing to displacement. The two accessory vesicles lie closely pressed together, and are bound up in a common sheath of specialized parenchyma. The glandular cells of the dorsal chamber of the antrum are well developed, but there is no secretion present either in the accessory vesicles or ducts.

The following table records the distribution of known species of this genus:—

	Mediterranean Sea	Atlantic Ocean		Indian Ocean[1]	Pacific Ocean		Polynesia
		English Channel	East Coast of North America	Maldives	Japan	Hong Kong	
1. P. siphunculus ...	*	*	...	...	...	...	...
2. P. dohrni	*	...	...	...	...	...	...
3. P. pellucidum[2] ...	*	...	...	...	...	...	...
4. P. sparsum	...	...	...	...	*	...	...
5. P. obscurum	...	...	...	...	...	*	...
6. P. tenebrosum ...	...	...	...	...	...	*	...
7. P. cribriarium ...	...	...	...	...	*	...	...
8. P. constipatum ...	...	...	...	...	*	...	...
9. P. elegans	...	...	...	*	...	...	...
10. P. cooperi	...	...	...	*	...	...	...
11. P. gracile	...	...	*	...	...	...	...
12. P. grande[3]	...	...	...	...	*	*	*
13. P. nationalis[4] ...	...	...	*	...	...	...	...

[NOTE. ON A SPECIMEN FROM CEYLON.

I take this opportunity of figuring and describing very briefly a typical *Cestoplana* obtained by Mr Stanley Gardiner off the Weligama reef, Ceylon.

Cestoplana ceylanica sp. n.

Very closely allied to *C. rubrocincta*.

Length about 65 mm., breadth 9 mm.

Anterior end of the body pointed. Colour (in the spirit specimen) dull gray with traces of a darker margin.

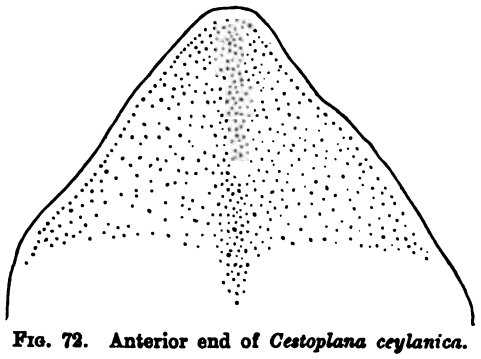


FIG. 72. Anterior end of *Cestoplana ceylanica*.

[1] Add an undescribed species from Ceylon.

[2] Doubtful species.

[3] It is possible that under this name more than one species is included by Lang, in fact different authors have described species from these three localities as distinct, but their descriptions are insufficient.

[4] See von Plehn [11].

Eye-spots (see Fig. 72) much as in *C. rubrocincta*, but the hinder margin of the eye-bearing area is straighter.]

II. NOTES AND CONCLUSIONS.

Most of the species described above have been examined by means of serial sections, the only satisfactory method of dealing with preserved specimens of this group. In some cases, however, I found it practicable to diagnose species sufficiently without having recourse to sections. This was especially the case with various specimens belonging to *Pseudoceros*.

I have not attempted to deal at all fully with the anatomy of any specimen described in the foregoing account, partly because space did not permit of my doing so and partly because Lang's Monograph has rendered it unnecessary. For fuller information concerning the anatomy of certain species of *Planocera* reference may be made to von Graff [6], and a very full account of the genus *Thysanozoon* has been given by von Stummer-Traunfels [14].

PLANOCERA AND A NEW GENUS. Lang divides the genus Planocera as defined by him into two groups, A and B. These groups may briefly be defined as follows:—

A. Five to seven pairs of branches from the main gut. Penis cylindrical, its lumen lined with chitinous spines; lying in a muscular outer sheath. Female apparatus provided with a muscular bursa copulatrix.

B. Gut branches numerous. Penis styliform; no bursa copulatrix.

The really striking anatomical distinctions between the two groups argue equally marked physiological differences. That such exist is, I believe, shown by the fact that Wheeler [16] has proved that in *Pl. inquilina*, a species belonging to group B, hypodermic impregnation frequently occurs, in fact that in some cases the vagina may have no function other than that of a passage for the escape of fertilized eggs. A similar phenomenon may occur in other members of group B. On the other hand in group A the structure of the penis would preclude the possibility of hypodermic impregnation, whilst the presence of a large muscular bursa copulatrix indicates that fertilization is the result of a normal process of copulation. Such differences are quite sufficient to warrant the raising of the two groups to generic rank. The name *Planocera* must be retained for 'group A,' whilst for 'group B' I venture to suggest the name *Hoploplana*.

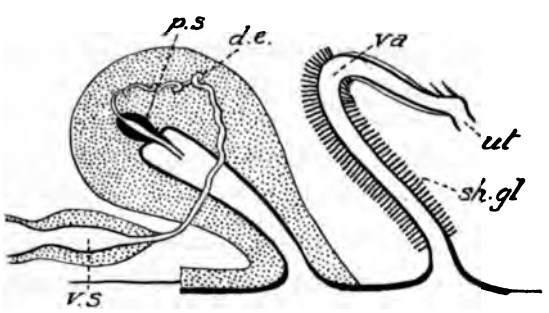


FIG. 73. Genital apparatus of *Hoploplana insignis* (after Lang). *va.* = vagina, *ut.* = uterus, *sh. gl.* = shell-gland, *v. s.* = vesicula seminalis, *p. s.* = penis, *d. e.* = ductus ejaculatorius.

In Fig. 73 copied from Lang the arrangement of the genital organs of *Hoploplana insignis* is shown. If this figure be compared with Pl. XV. fig. 12, the difference between a true *Planocera*, such as *Pl. armata*, and *Hoploplana* will be apparent.

The genus *Planocera* then as restricted may be defined in the same terms as group A is defined above, as Planoceroids with—Five to seven pairs of branches from the main gut. Penis cylindrical, its lumen lined with chitinous spines; lying in a muscular outer sheath. Female apparatus provided with a muscular bursa copulatrix.

It is obvious that *Pl. langii* differs more from any one of the other *Planocera* than they differ amongst themselves. The most pronounced differences are of course for the male apparatus the presence of paired vesiculae seminales, for the female the character of the bursa copulatrix, which appears to develope as an outgrowth from the vagina. I am inclined to suppose that an organ of a similar character occurs in Verrill's genus *Heterostylochus* [15]. In describing it he says of the female organs that, "a long narrow median duct runs far forward from the female orifice and expands into a flask-shaped seminal receptacle or spermatheca near the male organs; a swollen egg-duct also connects with the female orifice." The spermatheca may perhaps be the same organ that I have called the bursa copulatrix. Its true character may be judged from its appearance as shown in Pl. XV. fig. 13.

THYSANOZOON and THYSANOPLANA. Von Stummer-Traunfels [14] has recently suggested a modified definition of the genus *Thysanozoon* Grübe: "Pseudoceriden mit spitzohrähnlichen faltenförmigen Randtentakeln, mit zottenförmigen dorsalen Anhängen in welche bisweilen Divertikel der Darmäste hineintreten, ohne jedoch daselbst auszumünden: mit einfach oder doppelten männlichen Begattungsapparate."

The genus is thus made to include a number of tropical species, several new species being described in an interesting review of the genus by this author, who has also given a series of beautiful figures of most of the species. He finds that of all the species known to him only one, viz. *Thysanozoon brocchii*, has the dorsal papillae invaded by gut-diverticula. *Thysanozoon brocchii* and about six other species have paired male apparatus. *Th. auropunctatus* (Kel. Coll.) and several others have an unpaired penis.

Von Plehn [10] has described a new genus, *Thysanoplana*, containing two species evidently closely allied to *Thysanozoon*. It is separated from this genus on the following grounds. Firstly, "Im Gegensatz zu *Thysanozoon* der männliche Apparat ist unpaar." Secondly, "Hauptdarm mit zahlreichen vielfach übereinander entspringenden Darmastwurzeln." The papillae are stated definitely to be invaded by gut-diverticula.

Now if we accept von Stummer-Traunfels' amended definition of the genus *Thysanozoon*, it is evident that the first of the characters, viz. the unpaired male apparatus, will not serve to distinguish *Thysanoplana* from *Thysanozoon*, and as to the second I have found that a similar peculiarity, though much less marked, occurs in *Thysanozoon plehni* (mihi), whilst traces of the same occur even in *Thysanozoon brocchii* (see above). Accordingly in this case the generic name *Thysanoplana* cannot, I think, be maintained.

On the other hand, if we do not accept the amended definition and retain *Thysanoplana*, it will be necessary to subdivide *Thysanozoon* into several genera as follows:—

A. Species with gut-diverticula in papillae.
   - *a.* Penis unpaired (*Thysanoplana*).
   - *b.* Penis paired (*Thysanozoon brocchii*).

B. Species without gut-diverticula.
   - *a.* Penis unpaired (*Thysanozoon plehni*, etc.).
   - *b.* Penis paired (*Thysanozoon*, sp.).

The mode of origin of the gut-diverticula cannot, I consider, be employed as a generic character. On the whole it is simplest at present to refer all the described species to the

genus *Thysanozoon*, and consequently *Thysanoplana* must be referred to the synonymy of that genus. When it becomes advantageous to divide up the genus, the best guide to a correct grouping of the species will probably be found in the presence or absence of gut-diverticula in the dorsal papillae.

DISTRIBUTION IN THE INDIAN OCEAN. Great interest attaches to Mr Stanley Gardiner's collection owing to the fact that it is not only the first made in the neighbourhood of the Maldive and Laccadive Archipelagoes, but also that it is one of the largest ever made in the Indian Ocean; certainly the largest since the publication of Lang's Monograph. It is not of course possible on our present knowledge of exotic forms to discuss the distribution of marine Turbellaria, yet a few points are worthy of remark in connection with these specimens.

Firstly, it will be noted that the Euryleptidae are entirely lacking in the collection. We must not assume therefore that they are altogether absent from the reefs of the Archipelago, but we are certainly justified in supposing them to be of considerable rarity in that neighbourhood. This is the more remarkable when we remember that the Euryleptidae are well represented on the coast of Ceylon, and are known to occur in most seas.

I quote here an extract from Mr Gardiner's notes: "I have no lists, nor can I find any account of the Turbellaria round continental tropical coasts, on which to base any comparisons as to the relative abundance of the group in the Maldives. From a limited examination of some reefs at Weligama and off the Jaffna coast of Ceylon I am inclined to think that they are very much less abundant in the Maldives, both in number and variety of species."

Secondly, the relatively high percentage of Pseudoceridae in the collection is striking. In addition to the five or six species of *Pseudoceros* given in the systematic part there are fragments of a specimen, which must I believe be referred to this genus, but is too much broken to describe.

Probably the Prosthiostomidae and Cestoplanidae will prove to be abundant over the whole of the Indian Ocean, and we may expect to find, especially in the latter family, forms of great interest. I have in my possession a collection of Turbellaria made by Mr Evans near Penang. This collection contains not less than two new Cestoplanoids, one of them a very remarkable creature with a complete series of marginal eyes which are much more numerous than those of *Cestoplana maldivensis*; its body also is relatively much longer.

Lastly, the occurrence of *Pericelis byerleyana* and of *Leptoplana pardalis* in the Tropical Pacific as well as in the Maldives' Archipelago is of interest. Two other widely distributed species, *Leptoplana tremellaris* and *Thysanozoon brocchii*, are known, but both of these occur in north temperate as well as in tropical seas.

PARASITES. In none of the specimens in this collection, of which I have cut serial sections, have I found any gregarine parasite such as that which is found commonly in *Leptoplana tremellaris*[1]. On the other hand I would call special attention to the occurrence in two species, viz. *Planocera armata* and *Prosthiostomum elegans*, of bacteria or bacteria-like structures, which in both cases, but especially in the former, appear to occur only in certain definite situations.

GUT-DIVERTICULA. Similar gut-diverticula to those found in *Planocera armata* occur also in other Planoceroids. Whilst morphologically they are not unlike the diverticula which invade

[1] I have not been able to identify this species. *Discocelis tigrinia* is infested with *Ophiodina discocelidis* Mengazzini, which is probably closely allied to it.

the dorsal papillae of *Thysanozoon brocchii*, it may be questioned whether their function is similar. In *T. brocchii* on the one hand these diverticula may assist in the aeration of the tissues. In *Planocera armata* on the other hand it is difficult to suppose that they can have this function; I think it possible that they may rather be concerned in some way with nitrogenous secretion.

The function of the dorsal papillae of certain species of Thysanozoon, which contain no gut-diverticula, is also obscure. In *Thysanozoon plehni* the curious plug-like mass of tissue at the upper end of the diverticulum is to some extent suggestive of being connected with the function of excretion.

RELATIONSHIPS OF THE COTYLEA. In dealing with *Pericelis*, *Thysanozoon* and *Prosthiostomum* in the systematic part of this paper I have given a fairly full account of the male genital apparatus of each, so that it is possible to compare and contrast the three chief forms that this organ assumes in the Cotylea. The arrangement of the eye-spots in *Cestoplana maldivensis* and *Pericelis byerleyana* completely round the margin of the body is so far as at present known only paralleled in *Anonymus virilis*, *Cryptocelis*, and perhaps in *Heteroplana newtoni*. I believe that this marginal distribution of the eye-spots is to be regarded as a primitive character derived from a radially symmetrical ancestor.

In the *Cotylea* other indications of a radial structure are most strongly developed in *Anonymus virilis*. Such indications are the sub-central mouth and the numerous male organs grouped around the single female aperture. The presence of organs in this species bearing a general resemblance to nematocysts is probably also an ancestral character, so that if we adopt the usual theory and assume that the Polycladida are derived from an ancestor possessed of radial symmetry we are justified in regarding *Anonymus* as nearer to this ancestral form in certain respects than are the other Cotylea.

Intermediate between *Anonymus* and the higher Cotylea stands *Pericelis byerleyana*, the most interesting type in Mr Gardiner's collection. This approaches *Anonymus* in having marginal eyes and a sub-central mouth. Like this genus too it has a median indentation of the anterior margin, whilst the structure of its penis approaches that of the latter more closely than that of other Cotylea. On the other hand the possession of tentacles, a single penis and uterine vesicles, ally it rather to the higher Cotylea, such as the *Pseudoceridae* and *Euryleptidae*, whilst the extreme folding of the margin, the wide separation of the small tentacles and the backward position of the genital apertures serve to distinguish it sharply from all its allies.

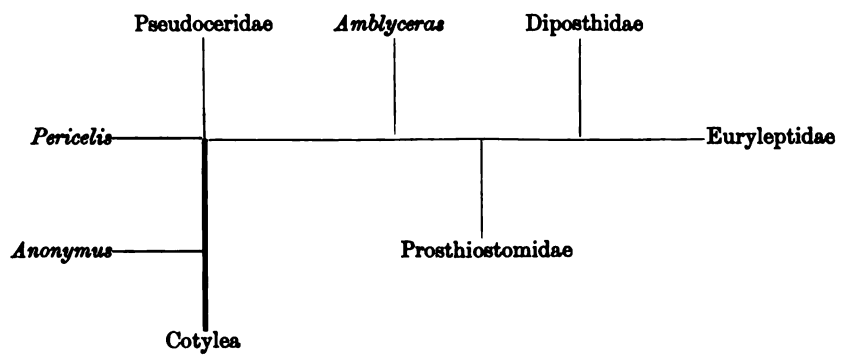
The marginal tentacles of *Pericelis* are of particular interest. They are of a simple and primitive character and indicate clearly the manner in which these organs have arisen in the Cotylea by the concentration of the marginal eyes on a pair of specialized folds of the margin. We can hardly doubt that this concentration has accompanied the acquisition of polarity in the organism in its development from a radially symmetrical ancestor. The fact that *Anonymus* has no tentacles, suggests the probability that this remarkable form is far more primitive than other Cotylea in that it has never acquired such organs.

A further development of the tentacles accompanied with the loss of the marginal eyes, save of such as have come into connection with the tentacles, gives us the condition found in the *Pseudoceridae* and *Euryleptidae*. The former family has a more primitive type of pharynx than the latter, in which it is tubular; in the *Pseudoceridae* it is not unlike that of *Anonymus* or *Pericelis*.

The *Prosthiostomidae* resemble the *Euryleptidae*, from which family they are probably derived, in possessing a tubular pharynx. They have no marginal tentacles, but the absence of these is probably secondary, perhaps a consequence of their elongated form. The structure of their male apparatus is very extraordinary, quite unlike that of other Polyclads.

Lastly, the family *Diposthidae* described by Woodworth [20] from the barrier reef of Australia is probably closely allied to the *Euryleptidae*, but unfortunately no account is given of the pharynx. *Amblyceras* is regarded by von Plehn [12] as intermediate between the *Pseudoceridae* and *Euryleptidae*.

The accompanying tree illustrates the presumed relationships of the Cotylea diagrammatically.



The characters of the terminal parts of the female apparatus give strong support to the view that the Cotylea constitute a perfectly natural group. In none of them is the vagina prolonged backwards beyond the point at which the uteri open into it to form an 'accessory vesicle' or receptaculum seminis; its walls are never developed to form a muscular 'bursa copulatrix,' and the shell-glands always open into it close to the gonopore. Whatever specialization of the female apparatus has been developed has occurred either in connection with the oviducts themselves as in *Oligocladus* or with the uteri as in *Pericelis* and *Diposthus*.

[The presence of an accessory vesicle in *Enantia*, as well as the arrangement of the eye-spots and the absence of a sucker form a combination of characters which forbid us to refer it, as Benham does [3], to Cotylea. In the possession of a gut anastomosis it does not by any means stand alone amongst the Acotylea, witness *Leptoplana pardalis*, *Planocera villosa*, *Eustylochus ellipticus*.]

Cotylea and Acotylea. The Acotylea can be distinguished broadly from the Cotylea by the fact that the former as a rule possess an accessory vesicle, a continuation of the vagina behind the point where it receives the uterine opening, though this is by no means invariably the case, *e.g.* the genus *Hoploplana*. But the most striking and most constant distinguishing feature (apart from the sucker) of the two divisions is afforded by the tentacles, when they are present. Those of the Cotylea have already been dealt with, and are of course universally marginal.

In the Acotylea marginal tentacles never occur; when they are present they lie dorsally immediately over the brain. In the *Leptoplanidae* and I believe in *Enantia* these tentacles, which in the *Planoceridae* always carry eye-spots, have been lost, the eye-spots connected with them have nevertheless been retained, at any rate in most cases. In the Cestoplanidæ so far as we know there are no traces of tentacles distinguishable (cf. the other elongated family,

Prosthiostomum). In speaking of the remarkable *Polypostia* Bergendal [1] remarks that 'tentacle eyes' can scarcely be distinguished. In passing we may notice that like *Anonymus*, *Polypostia* is provided with a number of male copulatory organs surrounding the female aperture. The fact is that some of the hinder pairs are not connected with the sperm-ducts. This is regarded by Lang as an indication that the penis in Polyclads is derived from glandular organs, which have only a secondary connection with the sperm-ducts. Whilst this is very probably true, it is possible that in *Polypostia* we have a stage in the disappearance of the multiple radially arranged penes that appear to be an ancestral character. In this connection reference may be made to the paired penes of certain *Pseudoceridae*.

ORIGIN OF NUCHAL TENTACLES. Of the origin of the tentacles of the Acotylea two views are held:—

(1) That adopted by Lang, who, following Chun, brings forward evidence for supposing the Polycladida to be derived from a Ctenophore-like ancestor; and homologizes the dorsal tentacles of the Planoceroids with the retractile tentacles of certain Ctenophores.

(2) That of Willey [17], who also derives the Polyclads from a radially symmetrical Ctenophore-like ancestor. He suggests that the dorsal tentacles of Polyclads are homologous with the sensory tentacles found in certain Ctenophores, and especially in Ctenoplana.

I here have to put forward a third suggestion, which differs completely from either of the preceding. Without questioning the probability of the origin of the Polyclads from a radial ancestral form, or the possibility of that form being also allied to a form ancestral to the Ctenophores, and avoiding any discussion as to the axial relationship of two groups, I consider that the tentacles of the Polyclads, whether marginal or nuchal,

(1) are a structure peculiar to the group;

(2) that they originated as marginal organs in connection with the eye-spots, somewhat in the way I have suggested above;

(3) that in the Cotylea they still retain this condition;

(4) that in the bulk of the Acotylea they have shifted back from the margin and come to lie dorsally.

This theory offers a more satisfactory explanation of the relationship of the Acotylea to the Cotylea than is possible on either of the two first. For, if we adopt either of these, we must suppose that the Cotylea are descended from forms which have lost all traces of the nuchal tentacles, and have in most cases acquired marginal tentacles. Now the *Leptoplanidae* have lost the dorsal or nuchal tentacles but have in almost every species retained evidence of their existence in the tentacle eye groups, whilst none of them have developed marginal tentacles, although some of them, *e.g. Discocelis*, have retained marginal eyes. On the other hand no Cotylean species ever exhibits any trace of a nuchal tentacle eye group.

On my theory there is no reason to regard the Cotylea as less primitive than the Acotylea; in fact the balance of evidence distinctly inclines to the opposite view. If we leave out of account the elongated, obviously highly specialized forms in either group, *i.e.* the *Prosthiostomidae* and *Cestoplanidae*, the Cotylea present far greater uniformity and less complexity of organization of the genital apparatus than we find in the Acotylea; whilst most

of the special features of the gut-branches of the Pseudoceridae (viz. dorsal diverticula of *Thysanozoon*, marginal pores of *Yungia*) are paralleled in the Planoceroids and in *Polyporus*.

Starting from a hypothetical, primitive, non-tentaculate form such as *Anonymus*, there is no difficulty in deriving both the Cotylea and Acotylea from it, if we admit that the tentacles in the two groups are homologous. There is no difficulty in supposing the margin of the body to have coalesced in front of the tentacles, and these latter to have moved back carrying their eyes with them, and come into connection with the dorsi-ventral muscles. As will be seen, this theory accounts readily for the presence of eye-spots in connection with nuchal tentacles.

There is a possibility that some of the more primitive Acotylea may be directly descended from forms that have never developed tentacles, but evidence on this point is lacking. On the whole I think that the balance of evidence inclines strongly to the view I have here advanced, which has the advantage of being better correlated with what is known of the anatomy of the group[1].

NATURAL HISTORY NOTES. I append some interesting notes given me by Mr Gardiner:—

"All the forms were preserved with $HgCl_2$; but, however much they may be expanded, all contract when the corrosive sublimate solution is poured on them, hot or cold. Anaesthetization by cocaine was useless, for, without keeping the animal quiet and expanded, it caused the excretion of a large quantity of mucus and this prevented the fixing fluid from getting at the tissues. Usually in cocaine, too, the animal began to rot and break up before it was sufficiently quiet to be killed. Chloral hydrate seemed to have little effect and alcohol did not begin to act for some hours, and as soon as the animal became quiet it began to secrete mucus, a fatal difficulty. The best way to preserve would be, I believe, to drop specimens straight into a bottle of $HgCl_2$ on the reef itself or into strong—at least 10 per cent.—formaline, removing after 15—30 seconds into concentrated corrosive.

"It is almost impossible to get the *Thysanozoons* off the rocks, as they break up readily. With all forms the only really effective way is to tease them and make them project themselves into glass tubes. A large *Thysanozoon* (?) secreted an enormous amount of mucus, and broke up rapidly into separate pieces; its mucus collected a large amount of dirt, and killed the other animals in the bottle. It also extruded a quantity of faecal matter. The smooth-skinned forms do not secrete so much mucus, but really each form requires to be placed at once and killed in a separate vessel.

"I carefully examined for the food of these Platyhelminths and found them browsing on Tunicate colonies and sponges, whilst others had been eaten by them under the same stones. Weed was not generally touched, but dead animal-matter laid down under stones proved an attractive bait. They do not browse on *Cylicia*, *Coenopsammia*, nor any of the corals whose normal habitat is their own. Hydrozoa and Actinia too are not touched. Often at Hulule I turned over rocks which had Tunicate sponges and colonies of hydroids; but it was only the Tunicates that were generally attacked, the sponges being rarely touched.

"The Turbellaria live principally under stones and rock, especially where the latter is lying freely upon the reef. Sand is deleterious, and, if much of it is present, no forms will be found. When a rock is overturned the Planarians hurry off in all directions, some over

[1] I am aware that the embryological method lends no support so far as I know to this view, but neither does it make for either of the alternatives.

its edge, but the majority into any holes on its surface. If however the hand is placed over one, it will remain contented for some time in any damp spot and will not come into the light. That the latter in any strength is what the animals object to is clear, as in glass vessels they always get to the side away from it and hide under the lee of any stones which may be placed in the water.

"It is noteworthy that the Turbellaria do not generally occur on reefs or reef-patches within the lagoons, nor indeed where there is not an ample change of water. The animals are never found on growing coral, perhaps on account of the light.

"The colours are in no sense protective, nor do I think they can be warning. I have never seen, either on the reef or in basins, any free-living animals attack them, though I have expressly placed various species together in glass beakers for this purpose.

"I would suggest that the pigment is respiratory. It is, I believe, quite true for each species. Under any rock mass it is common to find many Tunicate colonies of one species, and one species only. This may be white, red, pink, blue, or purple, yet the Turbellaria did not appear to me to differ in colour under different masses of rocks."

In conclusion, my thanks are due to Mr Stanley Gardiner for giving me the opportunity of undertaking this work, and to Dr Gamble for much assistance with regard to literature. To both these gentlemen I am indebted for useful advice and suggestions. I have also to thank Professor Hickson, both for permission to carry out my examination of this collection in the Zoological Laboratory at Owens College and for the kind interest he has displayed in the work.

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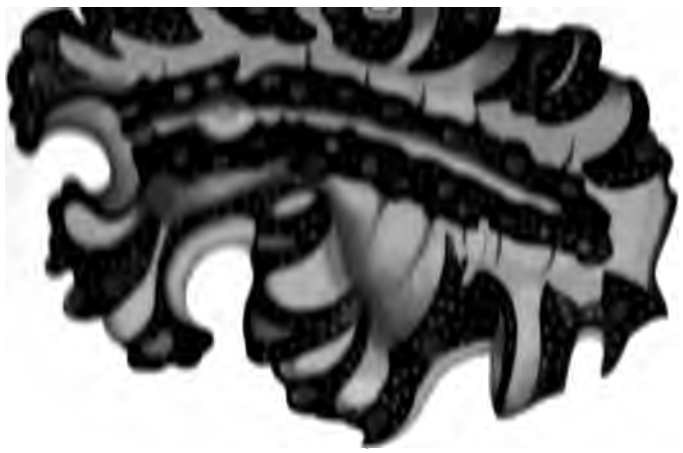

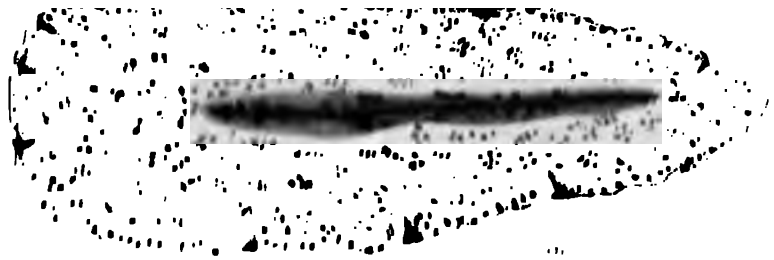

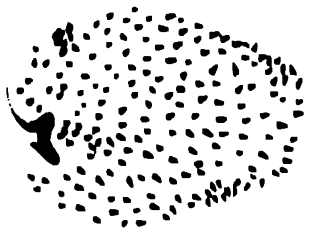

EXPLANATION OF PLATES.

♂ = male aperture.
♀ = female aperture.
a.d. = accessory duct.
a.m. = antrum masculinum.
a.v. = accessory vesicle.
b.c. = bursa copulatrix.
c = chitinous stylet.
c.d. = common duct.
c.e. = columnar epithelium.
c.h. = chitinous hooks.
c.r. = chitinous ring.
c.s. = chitinous spines.
d = gut-diverticulum (of *Planocera armata*).
d.e. = ductus ejaculatorius.
e.t. = tentacle-eyes.
h = hyaline layer.
hy = hyaline secretory bodies.
n = nervous tissue
o.s. = outer sheath.
p = pigment.
p.g. = pigment granules.
p.m. = pigment mass.
pe = penis.
pl = fold of lining wall of the penis.
pr = prostate gland.
p.r. = pseudorhabdites.
p.m. = intrinsic muscles of the penis.
p.s. = penis sheath.
r = rod-like bodies or bacteria.
r.m. = retractor muscles.
rh = rhabdites.
s = secretion.
s.g. = shell-glands.
s.p. = dark secretory bodies.
u = uterus wall.
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va = vagina.
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y = cells resembling yolk-glands.
x = 'plug-like' tissue at the tip of a dorsal papilla.

PLATE XIV.

FIG. 1. *Planocera langii* n. sp.

FIG. 2. *Prosthiostomum cooperi* n. sp. Anterior third of adult specimen.

FIG. 3. *Pseudoceros tigrinus* n. sp.

FIG. 4. *Pseudoceros gardineri* n. sp. Tentacles, eye-spots of the dorsal surface and part of the anterior margin.

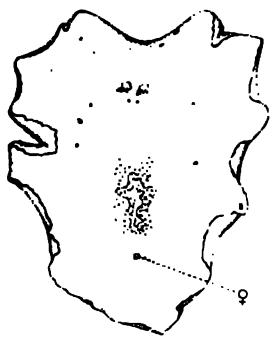
FIG. 5. *Pseudoceros punctatus* n. sp. for comparison with the preceding species.

FIG. 6. *Pericelis byerleyana* n. sp.

FIG. 7. *Thysanozoon plehni* n. sp.

FIG. 8. *Prosthiostomum elegans* n. sp.

FIG. 9. *Leptoplana pardalis* n. sp.



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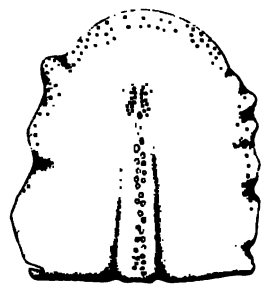

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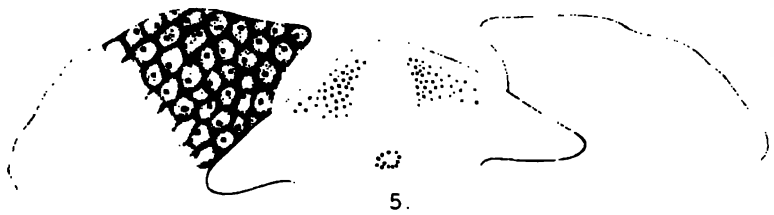

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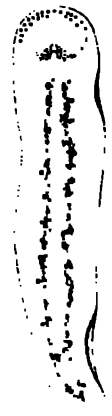

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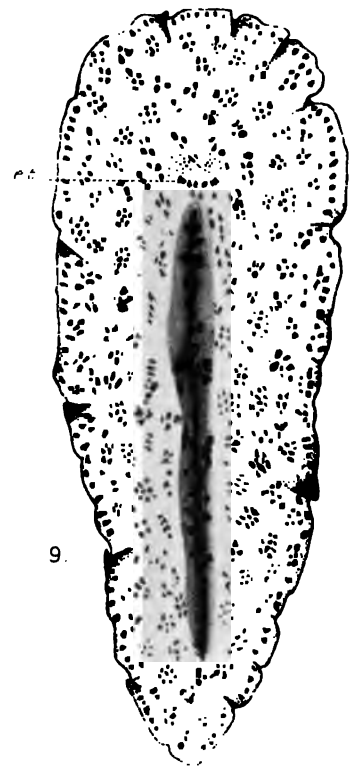

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FIG. 9. *Leptoplana pardalis* n. sp.

PLATE XV.

FIG. 10. *Planocera armata.* Transverse section across one of the gut branches, showing on its dorsal side a pouch-like diverticulum. × 500.

FIG. 11. Longitudinal median section through the genital apparatus of the same, reconstructed from transverse sections. Somewhat diagrammatic. × 60.

FIG. 12. Transverse section across the penis of the same at the level of the chitinous hooks. × 110.

FIG. 13. Transverse section of the penis of *Planocera langi* at the level of the pair of large folds projecting into the lumen. The section also passes through outer sheath and the 'receptaculum seminis.'

FIG. 14. Transverse section through the penis of *Leptoplana pardalis.*

FIG. 15. Longitudinal section through part of the oviduct of *Pericelis byerleyana,* passing also through one of the accessory uterine vesicles.

FIG. 16. Section passing transversely through part of the oviduct of the same.

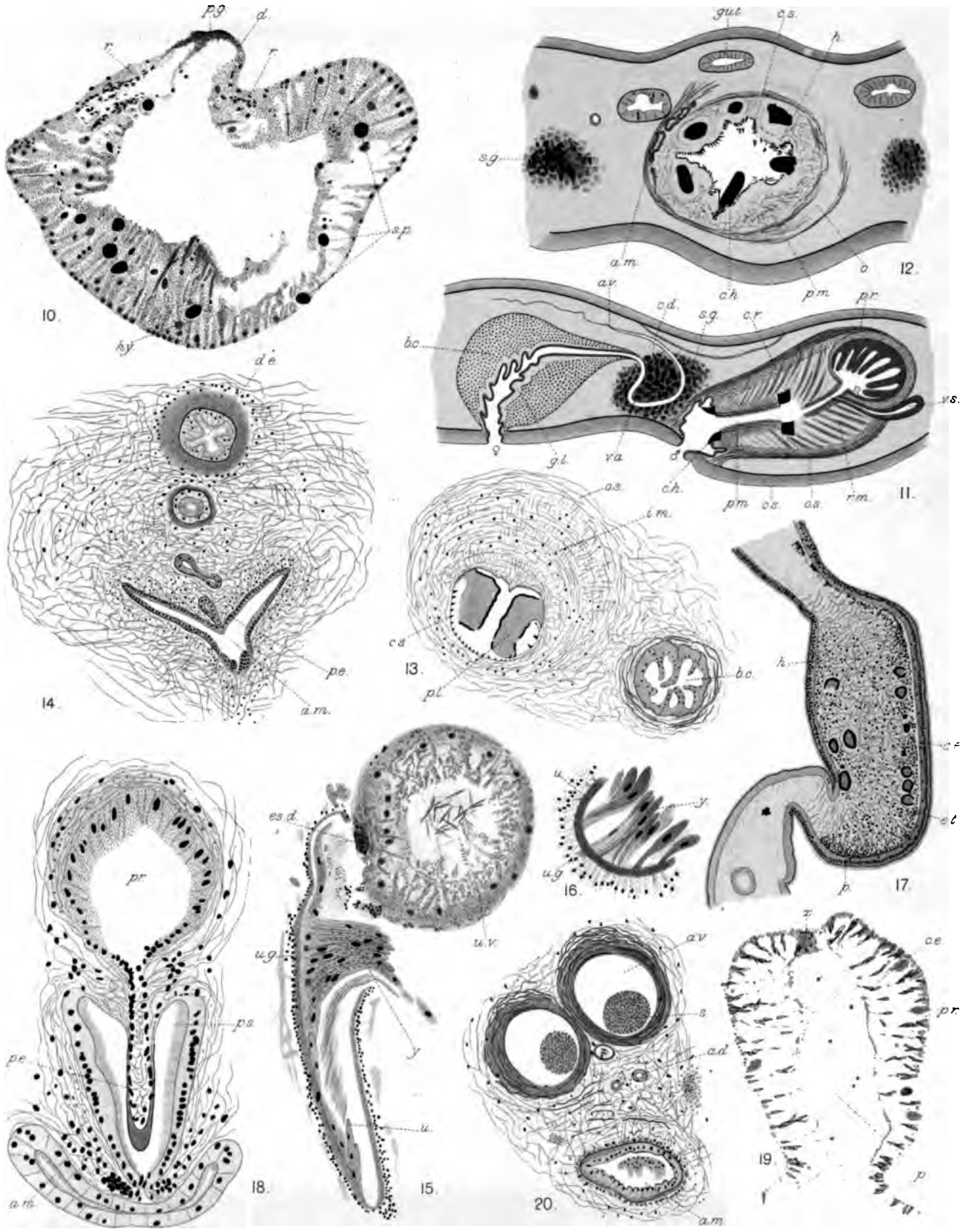
FIG. 17. Transverse section through a tentacle of the same showing the very regular columnar arrangement of the epithelium on the dorsal surface[1].

FIG. 18. Section through the penis of a specimen of *Pseudoceros gamblei.*

FIG. 19. Section through a dorsal papilla of *Thysanozoon plehni* showing the absence of any gut diverticulum; and the curious 'plug-like' mass of tissue (x) at the tip of the papilla.

FIG. 20. Section through the accessory vesicles of the penis and part of the antrum masculinum of *Prosthiostomum elegans.*

[1] Indicated by the lettering *c.e.*



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THE MALDIVE AND LACCADIVE GROUPS, WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN (*continued*).

By J. Stanley Gardiner, M.A., *Fellow of Gonville and Caius College, and late Balfour Student of the University of Cambridge.*

(With Plates XVI. and XVII. and Text-Figs. 74 and 75.)

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(*To be continued.*)

APPENDIX A.

SECTION I. THE SEAWARD SLOPES OF ATOLL REEFS.

I HAVE already repeatedly referred to the subject-matter of this Section in the previous Chapters of this Report (pp. 38—44 and 177). I have also therein stated that the reef is growing up everywhere outside the atolls (p. 49) without really attempting to show or prove that such is the case—to a certain extent assuming the upgrowth to be a matter beyond dispute. I have done so for two reasons, (1) to simplify the subject-matter in the previous chapters, and (2) because I felt that without a special, more detailed, yet somewhat generalised account of the whole seaward slope it would be impossible to satisfactorily show the evidence on which the above deduction was based. In the following pages I have attempted such a description, but I freely recognise that our investigations of the seaward slope in the Maldives were scarcely sufficiently complete to really warrant my doing so.

The outer or seaward slope of any bank in the Maldives opposite its encircling surface reefs is usually covered with a dense growth of corals and other organisms down to the depth at which the steep commences. The edge of the reef, although broken up by fissures extending into it for some distance, is usually fairly well-defined. Beyond it the seaward slope, as deep as the eye can see, *i.e.* to about 15 fathoms, is generally much broken up by masses and buttresses of the rock, the latter extending out at right angles from the reef, as well as by large colonies of corals. At least the latter evidently continue further out to 25 or 30 fathoms, the lead down to these depths often resting for a moment and then dropping off again for an additional 2 or 3 fathoms. The bottom, however, so far as the actual masses of the reef rock are concerned, actually becomes more level with each additional fathom of depth, until beyond 30 fathoms the reef-platform in the slope of its foundation rock is almost or quite level.

The reef edge and the area immediately outside it are extremely difficult and dangerous to examine on account of the rollers, which, always breaking to some extent even in dead calm weather, are followed by a strong outrush of water. The surface of the rock in this position is fairly smooth, being generally covered with incrusting *Lithothamnion* or with great colonies of a yellow Zoanthid Actinian. On those masses and buttresses, that are exposed in the backwash preceding each breaker, the upper surface of the rock is generally pitted, a little green weed often growing in its hollows. The sides of the masses commonly overhang, and are usually covered with *Lithothamnion*. Down to 5 fathoms the corals are of stunted growth and are only found in such hollows as are more or less protected from the rushes of water, which follow each breaker. The bottoms of the channels between the ridges usually appear white in colour, as if silted with small pebbles or coarse sand. In addition large coral masses may occasionally be distinguished. The filling up then of the fissures between the buttresses and masses would naturally to some extent follow their upward growth.

The dominant organisms in the formation of the masses of rock between the surface and 5 fathoms are undoubtedly those of the genus *Lithothamnion*. Unfortunately we know little or nothing about the mode or rate of growth of these plants, but the rate can scarcely be nearly as rapid as that of corals. The latter organisms may then perhaps be of far greater importance than the number or bulk of their living colonies in this area would at first sight lead anyone to suppose. That the reef is growing up admits of no doubt. In the few fragments of rock, I obtained between 1 and 5 fathoms, the species of *Lithothamnion* show a definite, though perchance somewhat irregular, layered growth. Boring organisms, etc. in them are rare, and neither they nor the corals of the area show any rotting of any sort. In Fiji I saw a few masses of rock broken off the edges of reefs in hurricanes and hurled back on to the reef flats, *i.e.* true negroheads. In the Maldives on the other hand, such negroheads do not exist on those reefs which fringe the open ocean. Moreover I never saw any sign whatever of the breaking off of definite masses of rock, either large or small, to seaward of any ordinary reef, nor for at least a dozen yards within its edge[1]. The absence, too, from the seaward shores of islands of fragments of coral or recent rock except such as grow or form on the reef flats proves of how little importance in the Maldives the destructive action, even of heavy gales, is on the edges of the reefs.

The next zone, 5 to 10 fathoms, shows a transition to the third, 10 to 15 fathoms. In the latter buttresses and masses are scarcely recognisable as such. No overhanging rocks with definite channels or fissures between are found. There is, nevertheless, a tendency for lines of low elevations—in section transverse to the slope appearing as rounded undulations—to run out at right angles to the reef behind, but even these are not always very distinct. Occasionally hollows, 2 fathoms or more deep, with sandy bottoms are seen, generally considerably overhung by growing corals. Such pools are, however, rare on those sides of the reefs, which are fully exposed to the ocean, but the whole of this area is sometimes represented by a succession of them. This is notably the condition, where the slope is protected from the full force of the ocean, such as against channels between atolls and against the central basin of the group, the Great Maldive Sea.

[1] In this connection I do not refer to the breaking off of branches of corals, etc. by the undercurrent on the reef slope, which follows each breaker (see p. 24). Any loose material may assist to fill in the hollows and crevices on the reef surface, but by far the greater part is undoubtedly carried out over the edge of the steep, thus extending the whole reef further and further seaward.

Even where the reef lies against the open sea, it is freely studded between 10 and 15 fathoms with species of nearly all the massive genera of corals, forming rounded colonies up to a few feet in diameter, often dead in the centre. The branching genera are not perhaps as numerous; where they occur the facies of their growth is that of low spreading thickets with very occasionally a larger tree of some vigorously growing species of *Madrepora* or *Pocillopora*, casting defiance at all law and reaching to within 3 or 4 fathoms of the surface. The reef in the above-mentioned, protected situations in many places appears to be almost completely covered with growing corals, which interlock, strive and struggle with one another in the same way and quite as much as, or even more than, on the most luxuriant lagoon reef in the whole group[1].

Lithothamnion may appear almost non-existent in a surface view, but on all outer slopes at this depth (10 to 15 fathoms), wherever a bare space is to be seen,—not a pit overhung by corals—there at the least a thin coating of the incrusting species of this organism will certainly be found. Sometimes the forms of the genus seem to grow into rounded or nodular masses, 2 to 3 feet or more in diameter, and standing up on the basal rock, but all such that I have examined have a basis—a central nodule—formed by some coral or other organism, which they have overgrown and perchance killed. Even in small masses of less than a foot in diameter a thickness for the nullipore of 2 to 3 inches is not unusual. In reality nearly everywhere these calcareous plants are growing at the bases of the corals. The coral colonies are ordinarily dominant, but, when one becomes sickly, the species of *Lithothamnion* soon claim sway, and extinguish it. In addition small, coarsely or finely branching growths of the same genus are also found, but these facies are of little importance as reef builders. Indeed the main significance of *Lithothamnion* lies in the peculiar mode of growth of its incrusting species. Whatever is reclaimed from the sea by any coral organism is secured by these plants, and firmly anchored once for all time to the reef so far as the action of the external ocean is concerned.

Dredging on the outer reefs is such uncertain work even in a steamer—and in addition so dangerous in a sailing vessel as to be almost impossible—that we could not afford the time necessary to make a proper study of the organisms below the depth of 15 fathoms, above which we could see what we were doing. Such organisms, as we secured from it, were only obtained while attempting to ascertain its general topography, of which I have already given a sufficiently full account.

[1] It is quite impossible to collect and investigate an area such as this without extremely calm weather, tackle of the strongest description, and most important a steamship.

A *Priestman's grab*, such as can be used by hand, seldom secures a coral of any massive genus and only broken stems of branching genera. The smaller massive colonies spread outwards at their attached bases, and the grab cannot be fixed on them. Moreover there is always some roll of the sea even in the calmest weather, and, when a coral mass of even 8 or 10 inches in breadth is securely fixed in the grab, a whaleboat or small launch will be pulled under the approaching waves before it be released.

The genera of the corals from 0 to 5 fathoms, forming only small colonies and the zone being difficult to examine, could not be accurately determined. Finely branching species of *Pocillopora* were, however, evidently by far the most abundant.

The following is a complete list of coral genera observed from 5 to 15 fathoms outside the reefs, the first 10 arranged in the order of their importance as builders in this position:

1.	*Madrepora.*	*Symphyllia.*
2.	*Pocillopora.*	*Merulina.*
3.	*Astraeopora.*	*Mussa.*
4.	*Orbicella.*	*Fungia.*
5.	*Astraea.*	*Pachyseris.*
6.	*Prionastraea.*	*Domoseris.*
7.	*Montipora.*	*Seriatopora.*
8.	*Coeloria.*	*Stylophora.*
9.	*Pavonia.*	*Anacropora.*
10.	*Porites.*	*Dendrophyllia.*
	——	*Millepora.*
	Leptoria.	

The gradual passage of the outer slope of any reef into a fairly smooth platform points to the fact that the foundations of the existing, encircling surface reefs of the atolls are really laid at some depth below 25 fathoms. Many of the same genera of branching corals (Madreporaria)—perhaps even the same species—occur at 30 fathoms as are found at 10 to 15 fathoms, but their form of growth is quite different. At the lesser depth the coralla are dense and heavy, the branches relatively thick and massive, and the colonies of large size compared with the sickly growths obtained at the greater depth. The genera of corals found at 15 fathoms are also mainly those that occur on the reefs, but at 30 fathoms additional genera make their appearance. Leaving genera of simple or of semi-simple species out of account, *Dendrophyllia*, *Goniopora* and *Alveopora* all grow in great luxuriance. Our swabs came up nearly every time thickly crowded with the branches of *Dendrophyllia ramea*, and many masses and fragments of the others were secured. Of even greater importance off Addu atoll was the Alcyonarian *Heliopora coerulea*, which was secured in each of six dredgings from 25 to 45 fathoms. Its facies were staghorn, lamellate and almost massive, and the quantity secured would show that large areas of the bottom must be covered by its colonies. In two of the dredgings pieces of the Hydrocoralline *Millepora* were obtained, and the same coral was also found incrusting a fragment of dead *Anacropora*. *Halimeda* is abundant, and *Lithothamnion* of incrusting or low branching facies also occurs. The position of the latter, nevertheless, is largely taken by incrustations of white *Polytrema*, to the importance of which Chapman[1] has lately drawn attention. Dead blocks of coral or other rock are not infrequent, and are generally completely or in great part covered by this organism. Of other animals, of little or no importance in building up reefs, it is only necessary to remark that this area is essentially the home of Gorgonians and Crinoids, while Alcyonaceans are very common. No deposit of sand or small rubble, be it observed, is ever found at these depths.

The most striking character of the whole of the seaward slope to the commencement of the steep, *i.e.* the reef platform, off the atolls of the Maldive group, is the almost complete clothing of the bottom with organisms of various kinds. The bare rock is practically nowhere exposed to the sea, so that the possibility of the latter eroding or dissolving away the rock must be over the whole outer slope largely discounted. All the corals and calcareous organisms, obtained from the reef platform, markedly differ from those off surface reefs or from lagoons, in that boring organisms are almost completely absent. Indeed all indications of change point to the active growth upwards of the whole bottom in this region of the seaward slope rather than to the possibility of its being by any means washing away.

Section II. The Formation of Lagoons.

The matter dealt with in this Section has already been to some extent considered in the preceding Chapters, but the subject is of wide interest in view of the various theories that have been propounded to account for the formation of coral atolls. There are also a few points to which attention should be more particularly drawn in the conditions at the present time of some of the atoll lagoons in the Maldive group.

Addu atoll[2], firstly, is of interest in that its lagoon is filling up rather than increasing

[1] *Jour. Linn. Soc.* vol. XXVIII. pp. 1 and 161.

[2] The work in this atoll was carried on in the intervals of fever, and was not nearly as complete as I could have desired. As it is, I am indebted to Mr Forster Cooper and Capt. Molony for all the soundings and most of the information about the lagoon.

in size and extent. There is between the land, wherever it exists, and the lagoon basin a flat of some sort, covered with dark, muddy sand, gradually getting whiter further out from the land. The inner part of this is to some extent exposed at low tide, and off Midu in the north-east corner the exposed area attains a breadth at springs of about 700 yards. Further at ordinary low tide neither this village nor Huludu can be approached even in a small dinghey within several hundred yards on account of this platform. The outward edge of the flat against the lagoon is quite well-defined—being covered with growing corals, *Lobophytum* and other organisms—and lies at a distance of about 1¼ miles from the land; its depth in this part is such that it can be conveniently waded at low tide, *i.e.* about 4 feet. The high water mark is about 3 feet up the beach, and, the tide being about 4 feet, there is thus in this corner a great platform, extending out for 1¼ miles from the

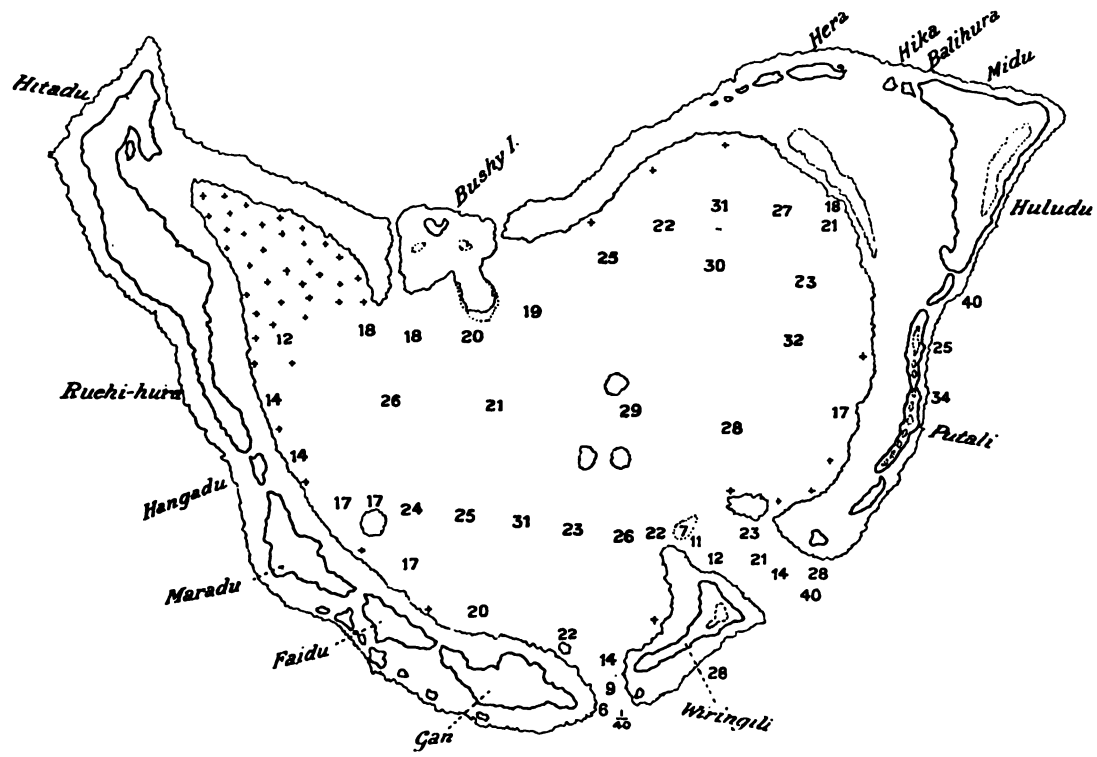

FIG. 74. Addu Atoll. The map is based on the Admiralty Chart, altered in accordance with the observations of the Expedition. Mr Forster Cooper's soundings alone are marked. Scale 2 miles to 1 inch. (*For changes compare the Admiralty Chart on* p. 150.)

land, with a slope in this distance of about 5 feet. This, however, is not all. Absolutely in the corner, not stretching for any distance either to the west or south, is a strip of deeper water averaging nearly 300 yards in breadth, separated by a second reef from the lagoon. This outer reef varies from 10 to 50 yards in breadth, and is rather patchy and ill-consolidated with no definite flat. It is built up almost entirely of corals, and approaches the surface so closely that it can only be crossed at low tide through certain definite channels. The *false velu*, as the inner lake or basin may be termed, has a general depth of about 5 fathoms, against which the enclosing reef forms a sloping wall. Towards the

atoll lagoon the slope of this same reef is nearly perpendicular, the depth immediately attained being generally greater than 8 fathoms, whence the bottom slopes to over 20 fathoms in about 150 yards.

The lagoon flat against the land in Addu atoll presents elsewhere more or less the same characters, but the deep inner channel is not found. Its edge against the lagoon is well-defined, precipitous, covered with coral and at about the low tide level. Within it there may be a slight hollowing out for 2 or 3 feet, but this shallow basin partakes rather of the nature of a boat channel and is in no way comparable to a velu. An analogy to the north-eastern velu is only found in the north-west horn, where a portion of the bay has almost been cut off from the atoll lagoon by the growth of coral knolls. The upper part near its head is a fairly clear basin, covered on the bottom with muddy sand. Towards its mouth, where it opens into the lagoon, these coral heads stud the whole surface, arising perpendicularly—perhaps overhanging at the top—from 10 fathoms or even deeper. Many of the knolls have grown together, so that a passage to the head of the bay is at the present time difficult for a vessel of any size, if not impossible. A basin or false velu is thus being formed by the upgrowth of a reef within the lagoon. Without having seen the growth of shoals in this horn it would have been difficult or impossible to diagnose the formation of the outer lagoon reef off the other (north-east) horn of the atoll. The analogy is, however, so close that there can be no reasonable doubt, but that it arose in the same way.

The coral growth, taken as a whole, in Addu lagoon is most extraordinary, and in vigour quite surpasses anything in my experience elsewhere either in the Maldives or in the Pacific Ocean. On all sides of the lagoon the reefs appear to have grown out into its basin, and fresh patches of coral are everywhere off them being built up towards the surface. The reef patch, charted by Moresby in 1836 to the north of the south-east passage, has become joined to the reef, and the horns on both sides of this same channel have grown further into the lagoon. Mr Forster Cooper in addition found a shoal patch with 6 fathoms immediately where the same passage embouches into the lagoon. Otherwise in the southern channels I could see no change either in depth or breadth, but the natives report that the two northern ones are now impassable for their vessels, while they seem to have been regularly used when Moresby surveyed the atoll.

The bottom of the lagoon was found by my companion, Mr Forster Cooper, to be covered with rubble and sand, one small patch of mud only existing at 27 fathoms to the head of the north-east horn. The rubble consisted of coral masses and shells on which were growing large trees of *Dendrophyllia*, colonies of *Madrepora* and *Pocillopora*, *Polytrema*, *Polyzoa*, great masses of *Alcyonacea*, *Halimeda* and sponges. The sand consisted merely of finer fragments of coral and other organisms, *Halimeda* remains and a few free bottom-living Foraminifera. Sedentary and indeed all other organisms were on this class of bottom singularly scarce.

Mr Forster Cooper investigated with soundings all parts of the lagoon, paying more particular attention to those, which were charted as having more than 30 fathoms of water. Making every allowance for the possibility that the soundings may have been too low—of which, nevertheless, there was no indication—the greatest depth obtained by my companion was 32 fathoms, where 36 fathoms ought to have been found. Where 39 fathoms are charted, only 31 fathoms were obtained. Isolated soundings may mean nothing on account of difficulty of fixation—in this atoll intensified by considerable changes in the land. Eliminating all but

the most careful observations—many having been taken when dredging—23 are left, all of which show a decrease in depth of from 1 to 8 fathoms, the general reduction being 2 or 3 fathoms.

It will be clear from the above remarks that Addu atoll differs from all others in our group in the fact that it shows a decrease in depth in its lagoon. Minutely examining all the factors as given above and comparing as far as possible with the chart, I estimate that in the 65 years between Moresby's visit and my own there has been *at the least* a decrease in depth of 2 fathoms over the whole area of the lagoon proper, *i.e.* about 15 square miles. The whole lagoon is about 22 square miles, and there must be taken into account the inward extension of the lagoon reefs, a far more rapid increase. To suppose therefore, for the 60 odd years since the survey, a deposit or filling in by coral growth of 2¼ inches a year over an area of 22 square miles does not seem to me to be excessive.

To account for this decrease, it should in the first place be pointed out that Addu atoll is markedly different in its topography to all the other banks of the group. From my corrected chart I estimate that five-sevenths of its circumference are protected by land. There are only four narrow passages—two extremely small—with an average depth over their whole sections of probably less than 10 fathoms. There is thus not likely to be much circulation of water in the deeper parts of the lagoon. The prevailing winds and currents are east and west; from the latitude being almost that of the equator it is obvious that they vary but little in different seasons of the year, inclining only somewhat to north-east and south-west. Further the ordinary currents and winds never can have the same force as in the more northern atolls, and hurricanes do not occur so far north or south. By a glance at the chart, it will be at once apparent that in no case can the usual currents or winds affect the lagoon, owing to the positions of the passages and the protection afforded by the land. As important factors in Addu, which they certainly are in other atolls, they may accordingly be neglected. The tidal rise and fall is stated to be 4 feet—on the lagoon beaches certain measurements I made averaged 3 feet 8 inches, but it does not follow that the rise within the lagoon would be as great as on the seaward sides of the islands—which is certainly less than in any other part of the group. Lastly, the encircling reef of Addu averages more in breadth than that of any other Maldivan atoll, and the tidal water in crossing it would be more likely to be saturated with lime before ever it got to the lagoon, so that there could be by its means little solution.

The chief agent in this filling in of the lagoon of Addu atoll is coral growth. Its luxuriance is quite without parallel in any of the described regions of the world, similar in the size and closed character of the area. I have unfortunately no definite observations, which serve to explain its cause. The water of the lagoon, owing to its protection from winds and currents, would naturally be considerably clearer than in most basins. The periphery, over which the surface fauna might be supposed to pass to the interior of the lagoon, is only 8 miles, but I would emphasise the fact that *all those kinds of corals that form the reefs feed rather by their commensal algae.* With regard to this it is probable that, from the decaying matter of the lagoon flats and land, an especially abundant supply of carbonic acid gas is provided. This would seem at first sight to be opposed to my argument that the tidal water would be saturated with lime before ever it reached the lagoon. All the carbonic dioxide would, I conceive, on account of the abundant growth of corals be utilised by them, but the sea-water has a solvent action on calcium carbonate, independent of the

presence or absence of this gas. The greater average and the lesser range of the temperature of the sea-water as compared with more northern and southern atolls (comp. Chagos Archipelago) would probably be an additional factor favourable to coral growth in this region. Lastly, destructive organisms of all kinds are relatively scarce in this lagoon. The larger boring animals are rarely found in the coral skeletons. Indeed in our record of dredgings I do not see a single form recorded, although in contrast to most atolls much rubble was obtained. This is further confirmed by a few corals, which we brought home from the area, in some pieces even the minuter boring sponges being absent. Holothurians and Sipunculids, the two most important sand-triturating forms in such an area, were singularly scarce both on the reefs and in the lagoon, so that there would be in the sea-water a lesser quantity of finely-suspended matter to be removed by the outgoing currents.

On the whole Addu undoubtedly owes the shoaling of its lagoon rather to want of solution than to the luxuriant growth of organisms, but, the greater the latter, the smaller are the solvent surfaces on which the sea-water can act. That Addu really had a considerably greater depth when Moresby's survey was made, and possibly still greater at a previous period, admits of no doubt. The reason of the relatively sudden filling in of its lagoon can only, I think, be ascribed to increase of land and decrease of depth in the passages, both tending to hinder the free circulation of the sea-water. Against this must be set the possible decrease of the area, from which sediment is supplied for filling in the lagoon. It appears to me doubtful, though, whether this would actually be the case or whether the effective source of sediment would not rather be enlarged with increase of land. The factor, however, is of small importance compared to the prevention of circulation in the water and hence of solution.

Finally, I may venture to remark that the physical conditions at this latitude are such that it is not unreasonable to suppose that the encircling reef of Addu atoll might have grown up from a greater depth than would be possible in the more northern parts of the Maldive group. The area of the shoal being small, the rim too might have been perfect from the first, and the lagoon would consequently have had a greater depth. In any case there is nothing in the existing conditions against the supposition that the lagoon may have been at one time greatly deepened by solution, while at present it is decidedly being filled in by coral growth and deposition of sediment.

Everywhere else in the Maldives such change as there has been in the lagoons has been one rather of loss than gain. In the first place the soundings show in the larger atolls an increase rather than a decrease. In dredging, a hard smooth bottom, free from rubble, was constantly found. The lagoon shoals generally fall almost perpendicularly to 20 and sometimes even to 30 fathoms, depths at which they could scarcely have originated in a lagoon. Great falls of rock from their sides are not infrequently found, while the amount of rubble around them is relatively small and forms but a very narrow circle. Boring organisms—so scarce in Addu atoll—are present in extraordinary abundance in other lagoons, and of great importance in destroying corals. The presence of much dead and decaying coral would perhaps provide an abundant supply of carbonic acid gas for solution on the lagoon floor, a position where much could not be absorbed by the corals.

The circulation of water in all the other atolls of the group is much greater than at Addu owing to their relatively much more extended, peripheral reefs, to which must be added the lesser percentage of their surface covered with land. The passages into their lagoons are generally both far more numerous and deeper, consequently producing a greater amount

of change in the sea-water. The currents of the two monsoons are important as well as the tidal current over the whole bank. With the banks close together and having deep passages these largely pass directly through the atoll basins. They thus sweep out small particles in suspension as well as frequently renew the water, so that the total amount of lime removed is greatly increased. The want of protection by land is important, for, whereas Addu lagoon with a westerly gale was quite calm and the water clear to 10 or 12 fathoms, Goifurfehendu and Bodu-faro (N. Mahlos) basins—both as completely enclosed by surface reefs—with not heavier winds were so churned up that the bottom was scarcely visible at 6 fathoms. The sea in rough weather was noticed to be quite milky even some miles off Suvadiva, Haddumati and North Male, while immediately off Addu it was comparatively clear. Even in calm weather the meshes of our tow-nets tended in passages to get blocked up with dead organic matter and fine mud in suspension, showing what enormous effect this sweeping out might have with a moderately rough sea. This movement of organic matter has another, an indirect effect in the formation of lagoons of infinitely more importance than its direct effect, *i.e.* in driving mud against the living reefs and corals, causing the extinction of small coral colonies and larvae, and enormously hampering the growth of larger masses. This effect of mud I have already drawn attention to in the Pacific. In the Maldives I had abundant opportunity of confirming my observations, and I would only here emphasise what I then wrote[1].

Important as the outwash of detritus really is, I cannot for a moment consider that it approaches solution in its effects in deepening lagoons after the reefs on a bank have assumed the definite atoll condition. On banks such as Suvadiva, Felidu, Kolumadulu and Haddumati considerable areas of the bottom must—owing to the perfection of these atoll-forms—be affected to an insufficient degree to greatly stir up their deposits, while probably the currents and winds would give an ample circulation for solution by the sea-water. That this is the case is clearly shown by the presence in protected situations of deposits of soft mud. Any deposit of the lagoons, however clean it may appear, has always a distinct amount of organic matter in the process of decay, this providing carbonic acid gas for the solution. The absence generally of deposition of calcium carbonate in dead coral masses in the larger lagoons—common in many of the smaller atolls and faro—would go to prove that there is no supersaturation by the lime, and hence that there is free circulation of the water.

Some of the muds are being examined by Sir John Murray, and will form the subject of a separate report. I however made a series of analyses to ascertain the silica (SiO_2) in a number of samples[2]. The analyses of 14 surface sands and rocks gave an average percentage of ·047 of silica, while three samples of mud from 40—50 fathoms from Suvadiva lagoon gave 2·441, the latter thus having about 50 times as much silica as is found in the surface rock. To put the matter in another way—admitting solution—about 50 volumes of the sand and rock from the reef and land would have to be dissolved to give the amount of silica found in 1 volume of the Suvadiva mud. No doubt some of the excess of silica in the latter may be explained by special causes, influencing its formation. Nevertheless I fail to see that any complete explanation can be afforded that does not take into consideration the solvent action of the sea.

[1] *Loc. cit.* p. 484, *et seq.*

[2] I am indebted to Mr M. M. Pattison Muir for placing the Chemical Laboratory of Gonville and Caius College at my disposal during the Easter vacation for these analyses, and

In conclusion, it is a fair deduction that the increase both in depth and extent in the lagoons of the Maldive atolls is mainly due to solution, an important additional factor being the outwash of fine matter by the tidal and oceanic currents. It is obvious, though, that there are two nicely balanced sets of conditions, causing the filling in or increase in size of any lagoon. A quantitative estimation of these, a comparison of the factors—analyses of the water at different states of the tide and from several parts of each lagoon, estimation of the amount of water entering or leaving each lagoon, areas of coral growth, etc.—would be useful, and could not fail to throw much desirable light on this most complicated question[1].

Section III. The Bathymetrical Limits of Coral-Reef Builders.

While the dredgings in the Maldive Archipelago were mainly taken to ascertain the general characters of the bottom and its fauna and flora in different positions, the situations were—by particular requests of various authorities on the formation of coral reefs—largely chosen with the view of ascertaining the depth to which the reef corals extend. Dredges of Naples and Plymouth designs and hempen swabs, 3 to 9 feet long, were largely used in addition to the Otter trawl and beam trawls of various patterns. The effectiveness of all these in procuring corals from shallow water, where the bottom could be seen, was carefully ascertained, and the trawls were additionally weighted with 2 or 4 old fire-bars for deeper work. During the time I had the steamer for dredging I chose some of the roughest, and hence most likely ground, between 30 and 50 fathoms, ultimately breaking or leaving most of my apparatus on the bottom. Much dead coral rock was brought up, some of it

also for giving me the assistance of trained attendants. Three to ten grams were taken of each sample after it had been well mixed, the whole carefully washed with distilled water and dried, and the organic matter burnt off. The amount of silica (SiO_2) was then estimated. The only metals found were Calcium, Magnesium, Aluminium and Iron.

	Material	Locality	Position	Percentage of Silica	Remarks
1.	Sand	Minikoi	Middle of Island, 6 feet deep	·028	
2.	Sand	Minikoi	Sea beach	·023	
3.	Sand	Minikoi	S. of lagoon, 1 fathom	·029	
4.	Sand	Minikoi	Centre of lagoon, 8 fathoms	·193	
5.	Sand	Minikoi	Reef flat	·026	
6.	Sandstone	Minikoi	Lagoon cliff at Honi-kodi	·071	Elevated rock
7.	Sandstone	Minikoi	Kodi point	·058	Elevated rock
8.	Sandstone	Minikoi	Seaward reef	·060	Elevated rock
9.	Coral-rock	Minikoi	Seaward reef	·076	Elevated rock; the sand infiltration between the corals
10.	Coral-rock	Minikoi	Seaward reef	·230	Elevated rock; consolidated mud between corals
11.	Coral-rock	Minikoi	Wiringili island	·044	Elevated rock; mixed corals and mud
12.	Sand	Hulule	Centre of island	·024	From a freshwater pool
13.	Sand	Suvadiva	Lagoon beach, Gadu	·006	
14.	Sand	Suvadiva	Lagoon beach, Havaru-Tinadu	·0013	
15.	Sandstone	Suvadiva	Lagoon beach, Wiringili	·0087	A recent rock
16.	Sandstone	Suvadiva	Sea beach	·0023	A recent rock
17.	Mud	Suvadiva	Lagoon, 40—50 fathoms, south	2·203	Two analyses
18.	Mud	Suvadiva	Lagoon, 40—50 fathoms, west	1·992	Two analyses
19.	Mud	Suvadiva	Lagoon, 40—50 fathoms, north	3·127	Two analyses

[1] Mr J. Lomas in a paper at the Brit. Ass. (Sept. 12, 1902) pointed out that the deposits in Palk Bay, Ceylon, are of ancient formation and prove a very extensive solution for that region.

consisting of blocks evidently free and some of masses showing fractures, where they had been broken off the bottom or still larger lumps.

The results were mainly negative, but the apparatus being thoroughly reliable and the dredgings fairly numerous, they may be relied upon. Series of dredgings in the same locality and habitat are repeatedly counted as single dredgings.

On the opposite page is a table showing the number of times *living* specimens of each of the different genera were obtained at various depths beyond 15 fathoms down to which the reef genera extend in great luxuriance.

The forms of growth are as follows:—*B.* branching: *C.B.* coarsely branching: *F.B.* finely branching: *S.B.* spreading branches: *F.* foliate: *I.* incrusting: *M.* massive: *S.M.* spreading massive: *S.* spreading.

A plain cross after the name, thus †, indicates that more than one species was represented.

The genera marked with a star * are to some extent doubtful, but serve sufficiently to show the facies and alliances of the species. *Domoseris* is almost certainly a synonym of some other genus, but I have been unable to examine any specimens of the allied genera.

The following genera of reef-building corals, characteristic of the Maldives, are not found in the collection:—*Coeloria, Leptoria, Prionastraea, Mussa* and *Symphyllia. Goniastraea* was only once obtained, and the *Orbicella* belong to species with small calicles, not found on reefs. The species of *Montipora* and *Hydnophora* and to some extent of *Astraea* and *Galaxea* belong to forms of growth widely differing from the large, characteristic, massive colonies, more generally found on reefs. *Madrepora* with increase of depth breaks up into thinner and finer branches and twigs; its stems ramify almost horizontally, and its calicles are widely separated from one another. *Pocillopora* alone varies but little, its colonies presenting the same two common, finely and coarsely branching, facies of growth, usually seen on reefs.

A few genera, not found at the surface, are evidently of great importance as builders between 20 and 40 fathoms. Of these *Dendrophyllia,* of which there is only one species, *D. ramea,* where found, appears generally to form great groves, immense quantities being obtained; some of its main branches were of large size, even 2 yards in length by 3 to 5 inches in diameter. An allied genus or a sub-genus, *Coenopsammia,* grows commonly on the under, shaded sides of stones on the reef, but was not dredged. *Gonipora* was found either as fixed, large masses, of which chips only were usually broken off, or free in mud or sand in a form allied to *G. stokesi. Alveopora* grew in large masses, usually much crushed when brought up, or in branches, the tips of which alone were alive. *Seriatopora* gave colonies either of extremely fine branches, or of finger-like stems. *Stylophora* was only secured on two occasions, both outside atolls, but the quantity of massive branches then brought up points to its being of no inconsiderable importance in this position. That the same genus should not be found on the reefs is peculiar, as it was one of the most numerous on Funafuti and other Pacific reefs. The specimens, placed under the genus *Trachypora,* represent modified incrusting *Pavonia,* which have taken to a deeper habitat.

The false corals, *Millepora* and *Heliopora,* have already been to some degree considered (pp. 314—317). In the accompanying table they supply 7 out of the 14 times surface-reef genera were dredged between 36 and 40 fathoms, and 3 out of 4—the genus of the fourth being doubtful—between 41 and 50 fathoms. I have never observed either of these genera on a

Table showing the number of times living specimens of the different coral genera were obtained at various depths.

Depth in Fathoms	Forms of Growth. 1st	Forms of Growth. 2nd	16—20	21—25	26—30	31—35	36—40	41—50	Found on Surface Reefs
Total Dredgings			29	65	55	33	31	23	R = Rare G = General C = Common
Dredgings having Corals			11	34	17	11	9	5	
1. *Stylophora* †	C.B.	—	1	3	—	—	—	—	—
2. *Seriatopora* †	F.B.	—	3	8	3	2	—	—	—
3. *Pocillopora* †	C.B.	F.B.	8	5	2	2	1	—	C.
4. *Madracis*	F.B.	—	—	1	—	—	—	—	—
5. *Euphyllia*	B.	—	4	—	—	—	1	—	G.
6. **Tridacophyllia*	S.	—	—	—	1	—	—	—	—
7. **Trachyphyllia*	F.	—	1	—	1	—	—	—	—
8. **Echinophyllia*	F.	—	—	1	—	—	—	—	—
9. *Echinopora* †	F.	—	—	1	—	1	—	—	—
10. *Merulina*	F.	—	—	1	1	—	—	—	R.
11. *Galaxea* †	M.	—	—	4	—	—	1	—	G.
12. *Goniastraea*	M.	—	1	—	—	—	—	—	C.
13. *Cyphastraea*	M.	S.	1	2	1	2	—	—	R.
14. *Hydnophora* †	M.	S.M.	—	2	1	—	—	—	G.
15. *Orbicella*	M.	—	—	1	1	—	—	—	C.
16. *Astraea* †	M.	S.M.	1	4	2	—	1	—	C.
17. *Siderastrea*	M.	—	1	—	—	—	—	—	R.
18. *Pavonia*	M.	B.	—	2	—	—	—	—	C.
19. *Sandalolitha*	—	—	—	1	—	—	—	—	—
20. **Trachypora* †	I.	F.	1	4	1	—	—	1	—
21. *Pachyseris*	S.	F.	1	—	1	—	—	—	—
22. **Domoseris* †	F.	I.	3	5	8	2	3	—	—
23. *Psammocora*	M.	—	1	2	—	—	—	—	C.
24. *Dendrophyllia*	B.	—	7	17	5	3	5	2	—
25. *Astraeopora*	M.	—	—	—	1	—	—	—	G.
26. *Turbinaria*	F.	—	2	—	—	—	—	1 (?)	R.
27. *Madrepora* †	C.B.	F.B.	7	11	3	2	2	—	C.
28. *Montipora* †	I.	B.	2	2	1	1	1	—	C.
29. *Alveopora* †	M.	C.B.	1	4	2	1	4	—	—
30. *Porites* †	I.	M.	1	2	—	—	—	—	C.
31. *Goniopora* †	M.	—	1	5	3	4	4	1	—
32. *Millepora*	B.	—	—	3	2	—	3	1	G.
33. *Heliopora*	B.	—	—	3	1	—	4	2	G.
SUMMARY: Total			45	94	41	20	30	8 (1 ?)	
SUMMARY: Reef Genera only			26	44	16	7	14	4 (1 ?)	
SUMMARY: Genera not reef			19	50	26	13	16	4	

true reef flat or in the fissure zone of any Maldivan reef, freely exposed to the sea. They are not important—if at all—builders on the outer slope down to 15 fathoms either against the open ocean or the Great Maldive Sea. On the other hand they are found in great clumps, up to 2 or 3 yards across, in boat channels and on sand flats as at Rotuma, usually the colonies having more or less lamellate facies. The recorded dredgings, where the two genera were obtained, were all in passages or outside atolls, and both were generally found living together. *Heliopora* had previously been obtained by Basset-Smith off the Macclesfield bank between 25 and 35 fathoms[1] and by the writer off Funafuti between 35 and 45 fathoms[2], and *Millepora* at about 25 fathoms, likewise off Funafuti[2]. Otherwise the genera were formerly regarded as essentially reef or surface forms. It is interesting to observe that absolutely no specimens of either were procured in the Maldives from between the surface and 20 fathoms, although *Millepora* at any rate was very abundant in all the passages into Funafuti lagoon, to 10 fathoms in depth. The specimens of both forms were mostly in the form of wide plate-like branches, although one incrusting specimen of *Millepora* was also secured. The quantity usually obtained, when either of these forms was dredged, shows that they are not improbably the most or among the most important of the reef-builders below a depth of 25 fathoms.

Among the other builders requiring consideration the most important is *Polytrema*, the significance of which lies in its power of binding together sand and rock. In the Maldives growths were obtained in practically every dredging, in which corals or fragments of rock were secured. In the passages *Polytrema* forms concentric incrustations round small pieces of coral or rock. Outside the atolls in soundings and dredgings it was obtained down to 125 fathoms, and its importance is probably very great. *Lithothamnion* was constantly present in dredgings outside reefs or in passages down to 45 fathoms, protecting dead coral or rock below 25 fathoms. Indeed the dredgings show that it is chiefly in this last quality that both this form and *Polytrema* are important, neither below 25 fathoms providing any considerable bulk of the material of which the reefs are built. *Halimeda* leaves, serving to fill in the hollows and the interstices of the other organisms, were constantly procured living down to 35 fathoms, beyond which its growth appeared to gradually die out. In Mahlos great beds of young oysters (apparently *Meleagrina margetifera*) were found at 25 fathoms, the shells of which would be of assistance.

Solitary corals have in the list been completely neglected, most genera having only a minute value in the formation of reefs. *Fungia* is sometimes found in great abundance on surface reefs, but was only once dredged, *i.e.* between 16 and 20 fathoms. An allied genus, *Diaseris* (probably synonymous with *Cycloseris*), was obtained living on nine occasions between 25 and 40 fathoms. In five of these dredgings the quantity of coralla—principally dead but also living—was very large, and in a tenth haul only dead specimens were secured. In the north passage into Suvadiva lagoon, 36 to 40 fathoms, in one haul of a 4½ feet beam trawl about 2 cwt. of dead masses of rock were brought up, mainly composed of the dead coralla of this genus, cemented together by sand and deposited carbonate of lime. A second dredging of the same passage, where it opens into the lagoon, gave great quantities of dead *Heteropsammia* in addition to a number of live specimens. In the same position the Snapper lead three times in succession brought up specimens of the dead coralla of this genus, the whole bottom appearing to be almost coated by them.

[1] *Ann. Mag. Nat. Hist.*, Nov. 1890, p. 358 *et seq.*

[2] *Loc. cit.* pp. 478—9.

In conclusion, I may at once remark that the above table absolutely negatives my previously-expressed view[1] that the reef corals probably live down to 40—50 fathoms in great luxuriance. Darwin in placing the extreme depth of flourishing banks of surface-reef corals at 25 fathoms was entirely correct. The specimens of these corals procured from beyond this depth show clearly in their growth that the increased depth is deleterious to them. At the same time the presence of a series of other genera of corals, which evidently flourish just beyond where the surface forms cease to exist, although with a considerable range in depth, is for the first time clearly demonstrated.

Section IV. The Rate of Growth of Corals and Reefs.

The formation of a reef is an exceedingly complex problem, in which a large variety of organisms all play their parts. The rate of growth of many reefs is doubtless infinitesimal. Our scientific interest lies mainly in considering the *probable* rate of growth on open banks freely exposed to the great ocean currents, while the practical interests of navigation require as well that the rate of growth within the lagoons of atolls should be accurately ascertained. Our practical interests demand the consideration of the *possible*, maximum rate of growth, while for the theory we require rather the knowledge of the *probable*, average rates of growth.

Freely exposed ocean banks and lagoons differ so profoundly in the structure of those reefs that have grown up actually on or in them, that any comparison is at first sight impossible. The lagoon reefs are more or less spongy structures, formed mainly of corals filled in with sand, while to build up formations outside an atoll requires a far greater complexity of organisms. The possible maximum rate of growth of a lagoon shoal is obviously the greatest rate of growth of corals in height in that position, the sand, etc., by which the corals are consolidated, not being necessarily formed by the decay of its organisms. These same shoals consist in the first place, until they reach the low tide limit, of mere coral heads, and their probable rate of growth up to this stage is not unlikely to be nearly equal to their possible rate. In addition the possible rate of lateral growth of such shoals is required for practical purposes. The tendency to and possibility of such kind of growth has already been sufficiently discussed in previous chapters, and need not detain us here. It is, peradventure, sufficient to point out that for navigation the accurate fixation of the central point of an ordinary shoal is all that is usually required with a rough contour and, of course, the soundings.

The rate of growth outside atolls is another matter. The general contour of the bottom is smooth, though hollows and pits occur. All its corals grow at about the same rate and so preserve its general contour. This doubtless is due to the strong outward current from the reef above, and is absolutely comparable to the level top of a plantation of firs, on a smooth, exposed hill-side. Rarely does any coral succeed in raising its head above the general level, and, when one does so, it is improbable that it is able to remain as a permanent structure. The loose material, that serves to fill in the interspace between the coral masses, consists mostly of coral fragments—derived principally from the reef flat above—and of free-living Foraminifera. *Lithothamnion* and *Polytrema* turn the whole into rock, loss being almost an unknown factor here. The rate of growth of the whole reef is, hence, not probably widely different from that of the individual corals that mainly serve to build it up. Once

[1] *Loc. cit.* p. 478, etc.

more it is to the rate of growth of the corals that we must look to get an idea of the possible and probable rates of the reef itself.

An almost insuperable difficulty for the consideration of our problem lies in the necessity of determining the rate of growth of the corals at different depths. There are no fixed laws for different species or even genera, but the rate is mainly affected in every case by the environment. When reef corals have once fairly fixed themselves on a shoal, the task of determining when that shoal will reach the surface, is as nothing compared to the difficulty of ascertaining the time that has been taken by the coral larvae to so secure themselves. The larvae must have a firm support, must in fact build up their houses on rocks, and it is owing to this that the growth of new shoals in lagoons is so rare. Above I only deal with reef corals; the task is many times magnified when we come to consider other forms. The problem, in truth, is one beset with innumerable difficulties, but one of such importance that any results, however small, are of great interest and value.

The facts relating to the growth of corals and reefs up to the year 1890 were ably summarised by Dana[1], whose conclusions are best expressed in his own words:—"Whatever the uncertainties it is evident that a reef increases in height or extent with extreme slowness. If the rate of upward progress is one-sixteenth of an inch a year, it would take for the addition of a single foot to its height, one hundred and ninety years, and *for five feet a thousand years.*" (The italics are Dana's, not mine.) This was published antecedent to the appearance of Murray's full work on the influence of pelagic organisms on the formation of rock[2], and it is evident that the possibilities of the enormous rate of increase of these and other organisms were not understood by Dana. Unfortunately I am unable to admit much of Dana's premiss, as I differ profoundly from him in regard to the structure of coral reefs and the mode of growth they exhibit at the present day.

Little work has been published on the subject since Dana's *resumé*. Agassiz gave a few photographs of the natural sizes of certain corals from a telegraph cable at a depth of 6—7 fathoms[3]. Taking the measurements from the figures of the specimens, these show a maximum upward rate of growth of respectively $3\frac{1}{4}$, 2 and 3 inches, and lateral extensions of $3\frac{1}{4}$, $1\frac{3}{4}$ and $2\frac{1}{4}$ inches, taking the halves of the total breadth of each, in seven years. More recently I discussed the rate of growth of certain specimens from Fiji[4], but with no attempt to deduce general conclusions as to the rate of reefs. Calculated out on Dana's method and remembering that practically the whole surface of a reef is covered with growing corals, the Fijian specimens would give an average rate of upward progress of 5·19 mm. in one year or a thickness of about 17 feet in 1000 years.

Many of the inhabited islands of the Maldives have definite channels for their small fishing and trading boats, excavated through their encircling reefs, even the shallowest usually with at least 4 feet of water at low tide. The boat channels between the land and reef accordingly make safe harbours for small vessels, and slips on the shores serve for repairing the latter. These canals, or *magu*—a naturally formed ship's passage, such as those into any of the lagoons, is termed in Maldivian *kandu*—by the laws and customs of the country are cleared out according to the needs of the different districts once every 2 to 5 years. In Mahlos, Male and atolls more particularly under the sway of the Sultan, the law is that this

[1] *Coral and Coral Islands*, 1890, pp. 123—127, 253—258, and 396—397.

[2] "Deep-Sea Deposits," *Challenger Reports*, 1891.

[3] *Bull. Mus. Comp. Zool.* vol. xx. p. 61 (1890).

[4] *Proc. Camb. Phil. Soc.* vol. xi. pt. iii. pp. 214—219 (1901).

shall be performed once in every 3 years. It is the duty of the *atoluveri*, or provincial governors, to see that this is carried out, and, as the duty fits in with the private interests of their officers, it may safely be assumed that it is properly performed. In Mahlos and Miladumadulu I saw—not at the time appreciating the stringency of this law—every range of living coral growth in these canals from 1 to 3 years of age. The bottoms of some were literally covered with corals, and, it was quite evident, would, if left alone, in the course of a very few years become completely blocked up. At Limbo-Kandu in N. Mahlos and Hurubudu in S. Mahlos, both of which were inhabited less than 20 and 30 years ago, the former canals could only be distinguished by the less consolidated nature and the narrowing of the reef, a growth of at least 4 feet in 20 and 30 years. At Fainu also in N. Mahlos what was originally the main passage, 5 feet deep, was abandoned in 1885, or 14 years before my visit. It was situated opposite the middle of a passage into the lagoon of the atoll, and must have been swept by strong currents, so that it decidedly could not have been in a position at all favourable for coral growth. Yet the whole bottom was so studded with branching and massive corals that the canal was not negotiable at low tide.

Innumerable other instances might be given, but they lack sufficient precision, whereas from the canal at Hulule I brought a number of corals, the maximum possible age of which from the ova is accurately known. Hulule is the most south-easterly island of North Male atoll, and is situated to the south of a large faro. There is a velu of moderate size, about 6 fathoms deep, to the north of the island but no other land, except a single island at the north end and a mere rock to the south. In its west reef, a little north of Hulule, are two small passages, kept open by the scour of the water across the faro and round the north end of this island. Opposite the middle of the land on the west side lies a small pool, where the Sultan moors his private yacht, 4 fathoms deep by about 40 yards across. Leading to this a canal had been cut through the reefs to a mean depth of 4 feet at low springs. This is regularly cleaned out once in every three years[1] under the inspection of officers from Male. The island belongs to the Sultan, and is regularly visited by him for religious purposes, the canal being at the same time examined to see that the work is properly performed. My collection was obtained in February, 1900, of the third year, and I visited the channel a second time at the beginning of the following April to secure additional specimens. However, in the mean time it had been cleaned out so thoroughly that not a single piece of living coral could be found; the whole bottom had been levelled, and the coral all removed. Any living fragments of coral, that possibly were left, could not in any case have continued to exist on account of the mud, with which the bottom was coated. The Sultan's annual visit was to take place in 1900 in the middle of May, so that it is safe to assume that it could not have taken place in 1897 until a month later. The work would in 1897 have been done before May, since later, the channel not being protected from the south-west monsoon, the job would have been attended with considerable difficulty. April would accordingly have been the last suitable month, and it is probable that its low spring tides were utilised for the work. The corals brought home would hence have taken

[1] It was very difficult in the Maldives to accurately ascertain measurements, either of time, length, or weight on account of Arab, or peculiar, in fact indigenous, standards being used. The numeration is in twelves, not tens, and Hindustani, Arab and Maldivan terminologies are all mixed. An isolated, tropical race of low culture is, in addition, not accustomed to think precisely.

I have throughout generally used the Maldivan (Mahommedan) year as equivalent to the European, so as to avoid possible exaggeration. One of the few exceptions is that which immediately follows, where I have allowed for the difference in number of days in calculating the times of the Sultan's visit to Hulule.

some period certainly less than 3 years, and probably not more than 2 years and 10 months, to have grown up from ova to their present size.

The physical conditions in the Hulule canal cannot be said to be especially inimical or favourable to coral growth. Strong currents pass in and out of the atoll between Hulule and Male, so that there is ample change in the neighbouring waters. The coral growth is luxuriant on the reefs to the west of Hulule, and the different corals grow fairly evenly in height, no genera being particularly vigorous. During the north-east monsoon there is a considerable sweeping out of mud, weed and sand from the shores of the island, which must be injurious to coral life. One may deduce from the appearance of the western passages into Minikoi atoll in the south-west monsoon, and from that of many of the artificial canals in the Maldives opening to the east in the north-east monsoon, that in the south-west monsoon the bottom of our canal would be swept bare of all sediment, absolutely down to the rock. The same canal, too, feeds no wide stretch of water so that the currents in it would not be of any great force. The canal, accordingly, in the south-west monsoon should be especially favourably situated for the growth of corals. Coral larvae could scarcely succeed in establishing themselves in the north-east monsoon on account of the mud, whereas the opposite monsoon should be most auspicious for their fixation. Indeed, it is probable that all the specimens would have commenced to grow in the latter monsoon, and that they would hence represent three growth periods of less than 3, 2 and 1 years.

The accompanying Table of the specimens serves to explain itself (p. 331). I have not yet worked out my coral collections, so that the naming of the species must be taken as only approximately correct. The important point is to know the form of growth in the genus—it is very unlikely that the rate of growth in a genus differs materially in closely-related species—and the specific name, or some other indication, is given in each case to show the facies. I have added to the form of my table, as originally published, the approximate horizontal area each coral covers in its position of growth, as far as the latter can be perceived, and also the height of each above its true horizontal base. As the colonies had been drying for two years, I have only given one weighing in this state. They were then soaked in water and weighed in the same until the resulting weight became constant; the volume alone, however, of the broken fragments was measured.

It is important to observe a second time that *the above specimens must all have grown up to their present size within a period of* 3 *years ab ovo. Further, they were all obtained out of an area of* 4 *square yards, or* 33416 *sq. cms.* Their position in the canal, some distance from its outer end but more or less in the centre, would certainly not theoretically have been the most luxuriant for coral growth, and indeed was selected rather as representative of the whole channel. Most of the corals were attached, and must have grown in the position in which they were obtained. The *Fungia* and two other free forms, *Orbicella* (No. 8) and *Montipora saxea* (No. 20), if they did not actually grow within the area, can only have originated in its immediate vicinity; in no case is it possible to suppose that they can have come from the reefs at the sides of the canal.

The rate of growth of the reef as a whole can be calculated for *say* 1000 *years* by several methods:—(1) The specific gravity of fine sand-rock being 2·48 (average of 10 samples), the corals may be estimated in this condition, and will give a deposit over the area of 85 cms. (2) With the specific gravity 1·78 (see Table), the deposit would be 123 cms. (3) Taking merely the area 3986 sq. cms., known to be actually covered by the corals themselves, the growth,

Table showing Rate of Growth of Coral Specimens from Hulule Canal.

			Name of Coral	Weight in grams	Volume in cc.	Specific Gravity	Area covered in sq. cms.	Height in cms.	Thickness as a sheet in cms.
Massive	Astraeidae	1.	*Goniastraea eximia*	81	46	1·76	25	4·2	1·84
		2.	" "	509	380	1·34	84	7·3	4·52
		3.	" (*Astraea* ?)	318	212	1·50	71	6·8	3·00
		4.	*Prionastraea abdita*	12	6	2·00	7	2·1	·86
		5.	" *tenella* (sp. ?)	218	103	2·11	34	7·9	3·03
		6.	*Acanthastraea grandis*	1094	660	1·65	221	5·8	2·98
		7.	*Cyphastraea savignyi*	230	128	1·79	55	6·1	2·33
		8.	*Orbicella* (sp. ?)	147	86	1·71	22	4·8	3·91
		9.	" "	571	287	1·99	81	8·2	3·54
		10.	*Coeloria daedalea*	325	156	2·08	48	6·2	3·25
		11.	" "	245	199	1·23	68	7·8	2·92
		12.	" "	321	203	1·58	72	7·3	2·82
		13.	*Hydnophora microcona*	309	161	1·92	74	7·1	2·17
		14.	*Symphyllia sinuosa*[1]	967	693	(1·39)	170	10·2	4·07
	Perforata Fungidae	15.	*Pavonia repens*	303	145	2·09	61	7·4	2·37
		16.	" "	769	410	1·81	113	10·1	3·63
		17.	*Psammocora* (sp. ?)	453	206	2·19	100	5·4	2·06
		18.	" "	1485	671	2·21	287	11·8	2·68
	Perforata	19.	*Montipora foveolata*	28	15	1·86	17	2·8	·88
		20.	*Montipora saxea*	590	271	2·17	84	9·6	3·23
		21.	*Astraeoporamyriophthalma*	214	103	2·08	42	6·0	2·45
	Free Fungidae	22.	*Fungia* (young)	47	19	2·47	27	2·2	·7
		23.	" "	25	10	2·5	18	1·7	·55
		24.	" *dentigera*	151	62	2·44	47	3·7	1·32
		25.	" "	357	127	2·81	72	4·0	1·76
		26.	" "	379	142	2·67	97	3·9	1·46
		27.	" "	452	171	2·64	103	4·3	1·66
Branching	Imperforata	28.	*Pocillopora coespitosa*	154	91	1·69	57	5·4	1·60
		29.	" *plicata*	228	137	1·66	80	8·3	1·71
		30.	" "	442	218	2·03	118	8·5	1·84
		31.	" "	531	248	2·14	126	12·7	1·97
		32.	" "	478	237	2·02	123	10·7	1·93
		33.	" "	693	426	1·62	139	15·0	3·06
	Perforata	34.	*Madrepora* (stunted)	68	32	2·13	18	5·2	1·77
		35.	" "	83	37	2·24	25	5·5	1·48
		36.	" (semi-massive)	343	173	1·98	33	15·6	5·24
		37.	" "	911	653	1·39	126	22·0	5·34
		38.	" (clump)	239	93	2·57	62	13·0	1·50
		39.	" (spreading)	463	237[2]	1·95	336	10·2	·70
		40.	*Porites* (dense clump)	739	544[2]	1·36	216	9·2	2·52
		41.	" " "	473	348	1·36	147	8·7	2·37
		42.	" (open branches)	346	218	1·58	155	9·1	1·42
		43.	*Psammocora contigua*	295	147	2·01	54	8·6	2·72
		44.	*Merulina* (genus ?)	60	37	1·62	38	2·3	·97
		45.	*Euphyllia glabrescens*	134	89	1·51	33	14·1	2·70

[1] A small colony of *Madrepora* of a much stunted growth was attached to the main mass of this coral. The Specific Gravity for the genus is hence quite erroneous.

[2] Calculated from Specific Gravity of fragments.

SUMMARY OF TABLE.

	Weight in grams	Volume in cc.	Specific Gravity	Area covered in sq. cms.	Height in cms.	Thickness as a sheet in cms.
1. Massive Astraeidae	5347	3320	1·61	1032	6·6 [1]	3·22
2. „ Fungidae	3010	1432	2 10	561	8·7 [1]	2·55
3. „ Perforata	832	389	2·14	143	6·1 [1]	2·72
4. Free Fungidae	1411	531	2·66	364	3·3 [1]	1·43
5. Branching Imperforata.....	2426	1357	1·78	643	10·1 [1]	2·11
6. „ Perforata	3665	2335	1·57	1118	10·9 [1]	2·08
7. The rest in List	489	273	1·78	125	8·3 [1]	2·18
	17180	9637	1·78	3986	7·7 [2]	2·42
Add Broken Fragments, etc.[3]	4781	3389	—	—	—	—
	21961	13026				

imagined as solid rock, would be 807 cms. (4) Estimating from the height of the fixed corals and assuming that the interspaces would be filled in by nullipores and material from other areas, the rate of growth would be 2567 cms. or about 14½ fathoms. If the *Fungia*, which lie between and under other corals, be added to the latter, the rate becomes nearly 16 fathoms in 1000 years.

The first two methods are quite erroneous, for, whereas the whole area of a growing reef would be covered with growing corals, only a small part in the area collected was so overgrown. The third gives a possible rate for an extremely poor area, where the corals, before they attain any size, are usually killed off by boring organisms or unfavourable conditions. The last is more useful, but assumes that the rate of increase in height is the same year by year in and throughout the life of any coral or reef. Organisms do not generally obey fixed mathematical laws, but the presumption is that, given the most perfect circumstances, a coral should increase both in the number of its polyps and size according to a regular geometrical progression[4]. The increase in height above is taken in arithmetical progression, which certainly must give too small results when based on the first 3 years of the existence of the corals. The area to the west of Hulule is not a particularly favourable one, but the conclusion that its reefs might grow at the rate of a fathom in about 60 years is certainly not too high.

The main interest of the problem lies in the rate of growth outwards of a reef, where it is freely exposed to the ocean, and the rate of upward growth of a reef on any oceanic bank, arising to within suitable depths from the surface. The inquiry is greatly complicated in such positions by questions of temperature, currents, exposure, depths, etc. The difficulty that the larvae have in affixing themselves could scarcely be much greater than in this canal at Hulule, while the other conditions on an open bank or on the outer slope of a reef would undoubtedly be more favourable. The vigour of the coral growth from 5 to 15 fathoms

[1] Average of all the specimens of the several classes.

[2] Average of the whole forty-five specimens added up separately.

[3] Mostly broken fragments of fine branching *Madrepora*, but also *Psammocora*, *Euphyllia* and *Pocillopora*.

[4] Against this might be set the natural death of corals by senescence—of which there is some evidence—but any vacancies are at once filled in by fresh coral growth.

outside atolls is certainly many times greater than within atolls, and in my opinion does not materially decrease until a depth of over 20 fathoms is attained. Until a surface reef be formed, or until the reef nearly reaches the surface, there is probably no outward sweeping of talus to spread the foundations of the whole. Interstices are filled in largely by nullipores and Foraminifera, or else bridged over. All the corals keep pace in their growth, and the rate of the whole reef would be the average rate of its corals.

Considering all the various factors, and particularly remembering the necessarily slower growth at the initiation of a reef and as it approaches close to the surface, it yet seems to me to be probable that an oceanic shoal at a depth of 25 fathoms might well in 1000 years, or even less, be covered with a perfect surface reef, built up by nullipores and reef corals. In effect, if Falcon Island, erupted to a height of about 250 feet in 1885 and now a mere shoal, be cut down to 25 fathoms by the end of this century—a by no means unlikely proposition—its place might well be marked by surface reefs, perhaps even by a perfect atoll considerably before the year 3000 A.D. Should these deductions be, as I believe, fairly accurate, a natural explanation is at once afforded of the rarity of submerged banks of all sorts in coral-reef areas as compared with surface atolls and reefs.

Section V. The Action of Boring and Sand-Feeding Organisms.

1. *General.*

The skeletons of the corals and other organisms of a reef are either built up into a coral limestone by the animals themselves, or are worn down into mud and sand. A third fate may, however, at any time befall them in being dissolved by the sea-water. It is obvious that as a rule the smaller the skeleton the greater must be the amount of surface that will be exposed to solution. Hence sand should be more acted upon, and should suffer more loss in weight, than corals, shells or nullipores. Now the ground-down skeletons of these organisms form the greater part of the sand, and it is most necessary to examine the means by which their massive skeletons are broken up.

The main destructive agents of reefs are, undoubtedly, marine animals and to a lesser degree plants, aided to some extent by the solvent action of the water and erosion by the currents. The destructive organisms have two modes of procedure. First they bore into corals and other skeletons, and so weaken them that they break either by their own weight or the motion of the sea. Indirectly they probably by their organic matter attract other animals to ingest the fragments and further break them down. The latter or second action, that of sand trituration, is of no small significance.

In actual number, the animals that depend on sand for their food in any atoll are probably more numerous than the boring or free-living forms, as undoubtedly they are the most difficult to get any adequate knowledge of. Besides breaking down the fragments of rock into sand, they are the main factors in the creation of mud. The deeper layers of the sand of a flat pass through their bodies again and again, being in all cases ejected in a still finer state on the surface of the bottom. With the ebb and flow of the tide, with storms, etc. much of the finest matter must pass into suspension in the sea-water, to be, perhaps, deposited outside the atoll. The influence of this outwash on the character of the bottom deposits outside reefs has been thoroughly established by the Challenger expedition, and there is no call for further comment here.

To quote Sir John Murray's Summary of his Report on Deep-Sea Deposits, "Coral Muds and Sands cover a large area in all coral-reef regions, estimated at about 2,700,000 square miles, including those from shallow water and also the area of the islands and of the lagoons and lagoon-channels. The coral-reef region of the Pacific is by far the most extensive, and there Coral Muds and Sands attain their maximum development, being estimated to occupy about 1,500,000 square miles; in the Atlantic they cover about 800,000 square miles, and in the Indian Ocean about 400,000 square miles[1]." The area in the slightest degree covered or enclosed by actual surface reefs in the Indian Ocean is certainly less than 25,000 square miles, so that the space actually covered by deposits, mainly formed from the same, is at least sixteen times as great. As to the rate of formation of the deposit Sir John Murray remarked:—"Around some coral reefs the accumulation must be rapid, for, although pelagic species with calcareous shells may be numerous in the surface waters, it is often impossible to detect more than an occasional pelagic shell among the other calcareous *débris* of the deposits[2]."

The main cause of the formation of lagoons is, assuredly, the solution of the calcium carbonate by the water, but the outwash of mud is an important and direct subsidiary cause. At the same time the mud has an indirect action as well, *i.e.* by preventing the growth of coral and other sedentary organisms on the floor of the atolls, and by constantly checking and restricting all such growth. This was an action repeatedly observed by us, but from its nature one almost incapable of direct estimation. I am here, however, more expressly concerned with the organisms which are the cause in their individual capacity, rather than the effect which they ultimately produce.

Although it is scarcely necessary, one is here impelled to refer to Darwin's work on "Vegetable Mould and Earthworms" in which he estimates that 10 tons of earth per acre annually pass through the bodies of earthworms, and are brought to the surface. The action of the reef organisms takes in not only the deeper sand but the surface material as well. It is independent of summer and winter, drought and frost, and in the smallest estimate could not be placed at less than 50 times as much as that of earthworms, with an erosive action by the average marine animal on the sand many times as strong.

The phenomena, however, are not confined to reefs, and have been demonstrated by Buchanan in the deposits of the ocean[3]:—"As the result I was led to believe that the principal agent in the comminution of the mineral matter found at the bottom of both deep and shallow seas and oceans is the ground fauna of the sea, which depends for its subsistence on the organic matter which it can extract from the mud." With this conclusion I cordially agree, but I do not think that the sand-feeding organisms of coral reefs have any considerable chemical action on the sand. The latter is always free from smell, even on mud flats, as off Huludu, Addu atoll, and, whether dry or wet, sulphuretted hydrogen (H_2S) is not given off, when acted upon by acid. The sand consists of almost pure carbonate of lime, and, although I sought carefully for any digestive action on the sand—the reaction of the contents of the gut was usually neutral, rarely alkaline—I failed to find any trace of such in the true, sand-feeding organisms[4]. The action of these forms, then, is purely one of trituration.

[1] p. 247.

[2] p. 411.

[3] "On the Occurrence of Sulphur in Marine Muds and Nodules, and its bearing on their Mode of Formation." *Proc. R. S. Edin.* vol. XVIII. pp. 17—39 (1890).

[4] I proved experimentally that *Lobophytum* and massive Astraeid corals will dissolve sand grains that may be taken into their coelentera. I have also found *Operculina* in *Flabellum* and other Foraminifera in *Coenopsammia*, with their shells completely or largely dissolved.

2. *Boring Organisms.*

Nearly all the skeletons of the living reef corals in the Maldives are riddled with boring sponges and algae. The algae all belong to one genus, probably *Achyla*, and seemingly to a single species. The sponges are of two kinds, those which form large spaces in the coral skeletons, which they themselves fill, and those whose presence is more or less imperceptible. The latter belong to the genus *Cliona* and probably like the algae to a single species. *Achyla* and *Cliona* resemble one another in their mode of growth. Their ramifications are most delicate, imperceptible to the unaided eye, and wander all over the coral skeleton. In *Pocillopora* their terminal filaments extend so close to the ends of the branches that only the very thinnest layer of corallum separates the polyp tissues from them. When a branch of this genus is decalcified and the polyp layer carefully stripped off, either of these boring organisms will be seen to have formed a close-meshed network, showing accurately the shape of the original branch with all its twigs.

The two genera do not in the Funafuti or other Pacific Ocean corals occur together, but whether they do so in those from the Maldives I cannot as yet say. To separate the two organisms a minute microscopic examination is required, but the presence of one or other in most reef corals is assured. The importance of these forms lies in the fact that they riddle the coral skeleton as soon as ever it is laid down. In the dead or decaying portions of coral masses they are not found; indeed, they seem generally themselves to die with the coral they inhabit. Of themselves they do not, so far as I have seen, directly cause decay, but presumably they show the way to other boring organisms, which certainly are not slow to follow. Their importance, indeed, is not improbably extremely great, but as yet little or nothing is known of their life histories, or modes of growth.

A second kind of sponge—apparently a Myxospongid—is of some importance for its action on corals, particularly within the lagoons of atolls. It apparently enters such coral colonies as are more or less dead at their attached ends—thus presenting bare surfaces not covered with polyps or epitheca—and hollows out cavities up to a square cm. in size or even larger, which it at once fills up with a mass of yellow or grey sponge. From one space it sends on its growths and excavates other cavities, thus perhaps completely riddling the base of the mass and causing it to fall. No connection with other boring animals was in any case observed or indicated, and the presumption necessarily is that it forms its cavities by the action of some acid secretion. The corals most affected by its growth were perforate forms, particularly *Madrepora*, but I also found it in many Astraeidae as well. An interesting point lies in the fact that this sponge seems to become more prevalent with increase of depth down to 50 fathoms, beyond which I do not know of its occurrence.

Of Mollusca *Lithodomus* (Mytilidae) is often very destructive, as it bores large, perfectly rounded holes up to 12 or 13 mm. in diameter through the coral masses. These often extend for several inches or even a foot or more straight through a colony, and, where one is found, there are usually a great number. The various holes seldom or never communicate with one another, and seem for the most part to run almost parallel. There is always a communication with the exterior through some dead part of the corallum, by which the animal entered in the first place, and the polyp tissues are sometimes broken through as well, the original hole then perhaps being plugged up by sponge or other growth. The animal has no preference for one kind of coral, but all are equally affected, the base of a Madrepore colony, the skeletons of massive *Porites* or Astraeidae, or even a thick branch of *Pocillopora*. *Lithodomus* was extremely

abundant in the velu of Hulule, while in Minikoi it was only once secured. Generally it was local in the Maldives, but, where present at all, it usually was found in considerable numbers. It never occurs in coral in an advanced state of decay nor in rock masses.

A second Mollusc, a small spiral Gastropod, is also in places abundant in corals, but whether it makes its own holes or not is uncertain. It may be as is *Vermetus* enclosed by the growth of the coral. In any case it is only local, mainly affecting *Leptoria* and other reef-loving Astraeidae.

Sipunculoidea are prominent forms in breaking up almost any large block of coral from any position on the reefs or from any depth found on them, but only the bases of branching colonies are affected. These borers are perhaps more numerous in lagoon masses than in blocks from seaward reefs. This may be due to the former generally being larger, and it may be that equally large colonies from say 10 fathoms outside and inside an atoll would be similarly affected. While not quite absent from dead coral-rock—of the reef flat or an upheaved pinnacle, etc.—the boring Sipunculids undoubtedly prefer a coral which is to some degree living. Their holes are perfectly round and smooth, and ramify in every direction through the coralla. In size they seldom exceed the half or third of the diameter the animal assumes when freed. How the holes are made is not in most genera quite clear. When in the living state, the bodies of none have any acid secretion, so that their holes are presumably made by friction. The body is slightly swollen out, and, the skin being rough, forms a firm support from which the animal can act. The genera represented were *Physcosoma*, *Phascolosoma*, *Aspidosiphon*, *Cloeosiphon*, and *Lithacrosiphon*, and an account of the species obtained with further notes will be found in Mr Shipley's Report on the Group (pp. 131—140).

Polychaeta are perhaps really the most important boring animals in coral rock, although the actual forms are inconspicuous and of small diameter. In coral reefs at least some specimens can be obtained from every rock below and between tide marks. All large coral masses are bored into and penetrated by their tubes, which bend and twist in every direction. The surface at the edge of the reef is made rotten for some inches by their borings, and the section of the broken base of a coral often appears as a regular sieve from their holes. The finer-textured corals are principally affected, but all corals and rocks are attacked, so long as they have a fixed base of support. Forms with calcareous or other tubes that grow with the corals are also bad, as they make them peculiarly brittle, and their holes form a lodgment for other organisms, whose subsequent destructive work is greater. From their prevalence in every rock be it of coral, sand or nullipore, the total effect of the Polychaeta must be enormous, and they must certainly be regarded as the prime and most effective agents in the breaking down of coral rocks.

Of the families of Polychaeta, found as borers in the corals and rocks of the Maldives, by far the most numerous and important are the Eunicidae, which in large numbers burrow into every rock and coral, extending in the latter up to and often penetrating the polyp tissues. They are the chief cause of the rotting of the rock of the reef flat, and are abundant in the lagoons as well, coral masses obtained from upwards of 40 fathoms being riddled by their holes. The Lumbriconereidae are less numerous, principally affecting recently formed coral, especially of the seaward reefs and passages. The Scoleciformia may bore into any rock, but are not common except in such as are already in a state of decay. The same remark applies also to the Phyllodocidae, but this family was far scarcer in the Maldives than at Funafuti. The Nereidae and Amphionomidae are not properly borers, but isolated forms may sometimes be found in tubes in the rock, which, if they have not made, they have certainly enlarged.

Their importance lies rather in the destruction of the slabs of beach-sandstone, in the soft sand under which they burrow causing them to split off. Of more markedly tubicolous forms Serpulidae and Sabellidae are common, but as to how far they are destructive I have no evidence.

Prof. M'Intosh[1], the great authority on the Polychaeta, whose opinion on this subject I requested, has been kind enough to give me the following note:—"I have not specially worked at the boring of Polychaeta in tropical waters, but from casual observations think that their action is not less than in European waters—probably more. Their action on calcareous rocks is very conspicuous even on our own shores—especially in the south. They form one of the most destructive agencies in wearing away those rocks—just as they do in the case of dead shells on the bottom of the ocean—ubique."

"Corals form a very suitable material for boring animals. I have not the slightest doubt that in tropical waters the boring Polychaets, such as *Polydora, Sabella, Dodecaria* and others are important agents in leading to the disintegration of rocks (especially calcareous and aluminous) and of shells and of loose calcareous stones."

Lithrotrya, a Cirripede, is a form, numerous on the seaward reefs of both Minikoi and Hulule. It generally inhabits holes in overhanging masses of the raised rock of the outer or seaward reefs. The animals attain a length of about 3 inches, and their holes extend in for about this distance from the under surface of the ledge. In suitable positions thousands may be present, riddling the whole surface of the rock. The regularity of their holes precludes the idea that they can have been made by any other organism. In life they hang downwards with their appendages just projecting out of their tubes, when their entrances are covered by water. No other Crustacea are true borers, but *Cryptochirus* and *Hapalocarcinus*[2] are of

[1] *Vide* "On the Boring of certain Annelids," *Ann. Mag. Nat. Hist.*, ser. 4, 1868, II. p. 276 and also "Notes from the Gatty Marine Laboratory. 5. On the Boring of *Polydora* in Australian Oysters," *Ann. Mag. Nat. Hist.*, ser. 7, 1902, LII. pp. 299—308, both by Prof. M'Intosh.

In the latter paper the author remarks that *Polydora* is a ubiquitous genus and well known as an active borer in shells, rocks and stones. He also quotes Prof. Leon Vaillant's estimate that there would be 250,000—300,000 *Polydora ciliata* in one superficial metre of the calcareous rocks at the mouth of the Somme.

Mr Cyril Crossland, who has recently returned from Zanzibar and Pemba, has favoured me with a note on the Polychaeta, the group on which he has been more particularly working. I do not, however, agree with some of his conclusions, and accordingly quote him at length:—

"The inner part and main mass of the reefs, which are formed of crystallised limestone, are too hard for any boring organism to touch, the only effect I have seen produced on this rock by any organism being the impression of the foot and shell of a *Patella*. The surface of the reef-edge to the depth of a few inches is soft, and this is much bored into by Eunicidae, the mud and sand they produce being matted together in this same position by filamentous algae. This in spite of its softness forms to some extent a protection to the reef edge, so that it effectively resists the action of the sea. The recently formed rock of the boat channel is also much bored, but not sufficiently to make any great difference to its cohesion.

"Polychaeta bore more especially in living coral, one or two specimens being found in most coral blocks when broken open. I do not think their effects are of much importance in Zanzibar in comparison to those of parasitic and aulophytic sponges. However weakened the coral may be at its base, it will in general remain in its position of growth.

"The bulk of my collection of Polychaeta was found in sand, or among weed and sponge. Their most important effects lie in the transformation of moderately coarse sand into fine mud. They are rare in very fine sand or in thin mud, seeming rather to require, to be present in any abundance, a fairly stiff mud or a sand coarse enough to cohere somewhat. In such positions their numbers are enormous (though their size is in general very small), and the amount of fine mud produced by them every year must be considerable. Wherever the sand is broken by the spade one sees innumerable, fine, red threads stretching across the crack, these being the bodies of small Lumbriconereidae and Capitellidae. Small tubeless Terebellidae also occur, but larger forms, Eunicidae and Scoleciformia, are not so abundant.

"The principal boring family in live coral is the Eunicidae, the commonest species attaining a length of about a foot and making an intricately twisted boring of corresponding length. Sabellidae make short, straight holes. Serpulidae render branches of Madrepores brittle by their tubes, which hollow them out, sometimes every branch of a clump containing a tube."

[2] *Vide* "Marine Crustaceans. III. Xanthidae and some other Crabs," in the same Part of this Publication.

assistance as maintaining open holes in the living corals, which frequently become later centres of decay.

Of other animals some Echinids and Patellids wear out holes in the rock, where they normally take up their positions in daylight. Ophiurids creep into any holes, however small, preventing them from being filled in with sand. *Bonellia* lives in cavities of the reef, often 1 to 2 feet below the surface, but is a rare form, and many Nemertines retire during the day to holes. None of these animals, however, are so far as I am aware actual borers.

3. *Sand-feeding Organisms.*

There are on reefs a very large number of animals that swallow sand, living presumably on the extremely small percentage of organic matter that it contains. It seems quite certain that the majority of these forms play some considerable part in the grinding up of the sand, but in most cases the process, by which they do so, is not quite clear. It will be seen later that all such sand-consuming forms have peculiar modifications of the gut, which adapt them in a singularly efficient manner for the consumption of such food as the sand contains.

It should here be pointed out that none of these sand-swallowing animals feed directly on living corals, breaking off branches, etc. The polyps are thoroughly well able to protect themselves against most free-living organisms. Indeed, so far as I have seen, a few Gastropods alone *make a practice* of consuming the polyps, leaving dead tracks over the otherwise living colonies. I do not know what author is responsible for the now common text-book statement that Holothurians browse on corals[1]. Even considering the anatomy of these animals, it is obvious that the statement cannot be accepted. Holothurians might, possibly, be able to suck off parts of the polyp layer, but that they could regularly break off coral branches, etc., is clearly impossible. Bits of recently dead corals may occasionally be found in their intestines, but I found by experiment that small living solitary corals and fragments of living coral were always rejected by the ordinary Holothurians of the reef at Minikoi. The actual animals that conceivably could feed on the reef corals of the Indian and Pacific oceans are extremely few, and certainly Holothurians are not among their number.

Holothurians are, however, from their great abundance on reefs the most important animals engaged in sand-consumption. The sand, wherever it is present under the stones of the boulder zone at Minikoi, commonly has living on its surface two or three species of brown and white forms, while in the sand itself a few small, transparent Synaptids are sure to be caught. A form, resembling *Synapta ooplax*, is common on lagoon beaches, often in enormous numbers. Holothurids, related to *Stichopus chloronotus* and *Holothuria atra*, are abundant on every reef. The former generally affects the seaward reef-flats and the encircling reef of the atoll, while the latter is found on all sand-flats and reefs within the lagoons. The two species, though, may sometimes be observed on the same area. Other forms of every conceivable colour up to 2 feet or more in length are also to be seen on the surface of the sand, many covered by its grains so as to be scarcely distinguishable. Large Synaptids, further, come out from overhanging coral masses every night, retiring during the heat of the day.

Most of the above are surface animals, but in addition to these there are numbers of species that live in and bore into the sand. A relatively thin, white species with dark brown spots,

[1] *Vide* "Coral Reefs," by Chas. Darwin, 3rd ed., p. 20. The statement, surely, does not rest on this one observation.

Holothuria maculata, was most conspicuous everywhere on the sand flats, attaining a length of 3 feet when extended. It makes burrows, up to 6 feet in depth, sometimes bent with two or more openings. At Minikoi, where the sand flat of the lagoon near the light-house was at low spring tides uncovered for some distance, the drying up appeared to stimulate these Holothurians to actively extrude their sand, and the whole flat every yard or so was studded with little masses of their pellets, which at once on the tide rising broke down into sand-heaps. 20 out of 52 of these castings from an especially rich area were scraped up and measured, giving an average of 37 c.c. for each animal. This, if spread out evenly, would cover the whole area to a depth of ·11 mm., or a layer of sand of over 40 mm. in thickness might be supposed in this area annually to pass through the bodies of this one species. In addition in every sieve full of sand from this same area large numbers of pink Synaptids, about 2 inches long, were obtained, which, if less conspicuous, probably passed still more sand through their bodies than the larger form just mentioned.

Holothurians are especially adapted to sand-feeding, in that they possess a conspicuous, ciliated groove to the gut. Besides extruding pellets many species also, or perhaps always, pass the sand through their bodies in a stream. The surface forms, mentioned above, feed during the night, remaining during the day more or less dormant. Of 63 specimens of *Stichopus chloronotus,* obtained at dawn between the large island at Minikoi and Wiringili, 59 had sand in the mouth part of the gut. This was absolutely the same as that covering the bottom, mostly clean sand with a little fine washings. The output of these forms seemed almost continuous during the day, and consisted of fine sand only. Of 31 specimens obtained about mid-day all had the fore part of the gut free and the mid part choked with coarse sand. A few, kept in a barrel and not allowed to feed, extruded some of their sand in pellets, but most retained it for 3 or 4 days, only getting rid of the finest particles. In ten specimens, kept in a sunken barrel and allowed to feed on fine sifted sand only, the mid part of the gut was found after 5 days to be still filled with coarser particles than any, which the animals had been given.

A Holothurian dredged from 43 fathoms, E.N.E. of Havaru-Tinadu, Suvadiva, was singularly interesting. It came from an area of the finest mud, which extended for 1½ miles in all directions from the spot where it was dredged. The mid-gut was, nevertheless, full of relatively large fragments of coral, *Halimeda* leaves, etc., the coarseness of the contents approaching such sand as ordinarily covers the bottom at 20 fathoms under a relatively strong current.

The sand of the mid-gut of all reef Holothurians, that I have examined, is always seen to be clean and the particles more or less rounded. In addition there is little loss on washing, while the sand in the first 3 inches of the gut commonly loses 2—8 per cent. of its weight in this process. Indeed, there is no doubt but that the coarser particles are detained in the gut for a considerable time—and probably worn down—while the sand and mud is by some means —presumably the ciliated groove—passed onwards. The extrusion of the whole gut and its subsequent regeneration is a process which commonly occurs in nature. It, not improbably, is for the purpose of getting rid of the very coarse sand, the exertions of the animal not being able to force it out in the form of pellets.

Of course different kinds of Holothurians may behave in diverse ways, but the total effect even of the two surface forms mentioned above must be enormous. The weight of sand, when dried, from 4 average specimens of *Holothuria atra,* taken in the early morning, was 297·3 grams. Of this 44·3 grams were extruded as fine particles into the bucket in 5 hours,

32·5 grams were found in the mouth or first part of the gut, there remaining for the rest of the intestine 220·5 grams of very coarse sand and fragments. A single, rather larger specimen, taken while evidently still feeding, had 190·7 grams of sand. Five other specimens, also taken in the early morning, extruded in the first 12 hours 47·9 grams of mostly fine matter. In the following night the coarse sand began to be got rid of, 49·4 grams being weighed making 97·3 grams for the first day. In the second day 121·4 grams were extruded, in the third 99·3 grams, in the fourth 67 grams and in the fifth 22·5 grams. The experiment was then concluded, 31·7 grams being weighed from the guts of the specimens, making a total weight of sand of 439·2 grams.

The specimens, recorded above, were obtained in fine weather in August, but of 55 specimens examined on July 6, 1899, after bad weather of some days duration, 19 had no sand in the gut at all, and only 18 of the remainder in the anterior part, showing that they had been feeding. The experiments required an accurate means of dividing the sand into its differently sized constituents. As it is, they merely show that the coarser particles are retained in the gut—being necessarily to some extent reduced in size—and also that there is in certain species a continuous passage of fine matter down the gut, presumably along its ciliated fold or groove. The latter or some similar organ is characteristic of most true sand-feeding animals, and probably in all cases functions in the same way.

Of other Echinoderms the Echinids[1] are also true sand-feeders, the gut in most forms being generally choked up with sand or small rock fragments. These animals, however, are of no great importance on coral reefs, the most numerous forms living on the reef flat, boulder zone or between branches of corals. *Echinomus cyclostomus* was found in some quantity in the sand of the flat at Hulule. The adaptation of the sub-order to this mode of feeding is seen in the animals possessing a furrow to the intestine or one or two siphons, which undoubtedly subserve the same function as the groove in Holothurians.

Ptychodera is also of great importance as a sand-feeder, though how far it actively triturates the sand—considering its feeble musculature—is dubious. The presence of ciliated grooves in the hepatic and abdominal regions of the gut indicates that the sand may be for some time retained, when some breaking down would be sure to be accomplished. The ejection of the sand is a rapid process, only taking a few minutes—all the species live in the sand, some having burrows of poor construction—and occurs at the surface, the animal at least in *P. carnosa*[2] slightly extruding its cloaca. No autotomy—so far as I have seen from the examination of several hundred castings—takes place in nature. The animal after ejecting its sand retreats again, but in *P. flava* and in *P. carnosa* still carries with it more than two-thirds of its original amount of sand. Further *P. flava*, if not irritated, retains its sand for a long time, attempts to keep the animal, until it had cleaned itself naturally, being quite futile for 4 days.

The importance of *Ptychodera*, where found at all, lies in its great abundance. The surfaces of sand flats throughout the Maldives are studded with the castings of *P. carnosa*, often 100 c.c. or more of sand. As Dr Willey said of them in the S. Pacific, "they form an important feature of the landscape at low tide[3]." Even more abundant in the sand of the lagoon at Minikoi was *P. flava*, but its distribution in the Maldives was local. Where it occurred, however, a single handful of sand was often found to contain 4 or 5 specimens.

[1] See Prof. Jeffrey Bell's Report on the Actinocyclidiate Echinoderms in the same Part of this Publication.

[2] I am indebted to Mr R. C. Punnett, who is working out the collection, for the names of these species.

[3] "Enteropneusta," Willey's *Zoological Results*, p. 256 (1899).

Apparently the same species often lives under beach sandstone masses, at Maduwari in S. Mahlos being present in enormous numbers in this position. *Spengelia* was also obtained, but, although a sand-feeder, was nowhere found in sufficient abundance for it to have any appreciable effect on the sand.

Next in importance come the species of the genus *Sipunculus*, which likewise possesses a ciliated groove to the gut. Mr A. E. Shipley, who has had considerable experience of tropical forms, in considering the Gephyrea (*Camb. Nat. Hist.*, vol. II. p. 422) remarks, "The food of Sipunculids seems to consist almost entirely of sand and their only nourishment must be such small microscopic organisms or particles of animal or vegetable *débris* as are to be found mixed with the sand. The alimentary canal is as a rule quite full of sand, and yet in spite of the tenuity of its walls they never seem to be ruptured. If the contents of the digestive tube be washed out with a pipette, it will be found that it requires considerable force to dislodge many of the sand-particles lying next the wall. These are more or less imbedded in crypts or pockets of the wall, and, as the sand passes along the intestine, they probably serve as more or less fixed hard points, against which the sharp edges of the sand particles are worn off. Amongst the sand are usually to be found pieces of shell, sometimes with a diameter equal to that of the alimentary canal; these are usually rounded but their angles may have been removed by attrition before they entered the mouth of the Sipunculid."

The animals of the genus (*Sipunculus*) are extraordinarily abundant on all coral reefs in certain positions, such as under dead corals or masses of rock. The quantity of sand that passes through their guts must be considerable, but much of it seems to be retained for a long period. It is too almost impossible by anaesthetisation to get the gut free from sand. The castings are relatively both small and fine in texture. The quantity of sand passing through the gut does not appear to be great, but what passes is much triturated. Perhaps therefore the total action of these animals may be of more importance than that of any other group. The species of our collection have already been reported on by Mr Shipley, under each its distribution being noted. I may, however, remark that *S. indicus* is found in large numbers on practically every sand flat in the Maldives.

Of other sand-feeders *Thalassema* may be mentioned, of the contents of the gut of which Shipley has given a list (p. 129). The genus is, however, rare on reefs. Polychaeta commonly swallow as they burrow in the sand, but I have no reason to suppose that the sand forms —although often very numerous—triturate the sand to any notable extent. This does not quite agree with Mr Crossland's view (p. 337), but against this may be mentioned M'Intosh's observation that the deep-sea Challenger forms often had Foraminifera and Radiolaria in their guts in an almost perfect state[1]. Much material, especially on the more muddy flats, must nevertheless pass through their bodies, and cannot but be to some slight degree affected.

Section VI. Beach Sandstone.

Large, linear masses of a friable sandstone, extending sometimes for great distances along the shores of the islands, are characteristic of coral atolls in whatever part of the world they may be found. So far as I have seen in the Maldives and elsewhere, these masses only occur in their typical condition (1) where there is a fringing reef or a sand flat of greater or lesser breadth extending out from the shore, or where the beach is by other

[1] "Annelida Polychaeta," *Challenger Reports*, p. ix. (1885).

means protected from the direct force of the waves; (2) where the beach is made up practically entirely of carbonate of lime formations; (3) where the beach is formed principally of sand and not of masses of rock; and (4) where the beach is at rest so far as growth outwards is concerned or washing away.

In respect to the first of the above conditions it is necessary that the beach for a sandstone formation to be found should be to a large extent protected from the heavy ocean rollers or the smaller but perhaps more persistent influences of the waves within large atolls. At Maduwari (Fig. 30) a little sandstone is found to the north of the island at the south side of an incipient lagoon. The beach is, however, protected by the north-east horn of the island, and the velu is as yet both shallow and small.

Each island, while forming land of a faro or atoll, has generally its own circumscribing or fringing reefs. If the island be situated on a faro as Hulule, Male atoll, or most of the islands to the west of North Mahlos, the reefs may be on one or all sides far distant and connected rather with the encircling reef of the faro. In all cases such an island lies on the reef, or is joined to the growing part of the reef on one or more sides by a shallow flat, no velu in the Maldives having even a single isolated island arising within it. The island indeed may have beach sandstone on any of its shores, but on the side towards the velu, unless there is a considerable sand-flat, beach rock is absent.

Isolated islands, which cover the greater part of their reef, such as most of those in Miladumadulu and to the east of North Mahlos, may, where other conditions are favourable, have sandstone on any side. That there should be a definite protecting flat or reef of some sort is, nevertheless, clearly necessary. On the seaward and lagoon ends of most of the encircling islands of Miladumadulu and Mahlos there is generally no sandstone. Sometimes to seaward the shore is rocky, but very generally sand is found of not greater coarseness than that which forms the rock of many of the lagoon islands. A comparison shows that the explanation is to be sought in the extent of the protection, *i.e.* in the breadth of the fringing reef. Thus on the east or seaward side of the three neighbouring islands of Kenurus, Fainu and Inguradu the reef is respectively about 30, 200 and 60 yards broad, and sandstone is only found on the corresponding shore of the second island.

The reason that there is no beach rock on the lagoon shores of so many of the encircling islands is very largely the same, particularly in the atolls mentioned above. The fringing reef is generally narrow or almost non-existent, and the sand washes to and fro on the beach with every tide. The whole beach, too, is never at rest nor in one condition for any length of time. The currents on each side of the island in the one monsoon form an eddy behind it, piling up sand, which the other monsoon, sweeping across the atoll lagoon, removes so that the beach is restored almost to its former state. For the same among other reasons the corals of the shore, alternately nearly killed by the sand and growing vigorously, are off many islands unable to form a definite fringing reef. The conditions are best seen on the east and west sides of the atolls, through the passages in which the currents attain their greatest force. Even to the north and south in the more open atolls sandstone is rarely found on the beaches of the islands towards the lagoons. To the south of Mahlosmadulu, however, between Hitadu and Defuri the rock is found just as frequently on the lagoon sides of the islands as towards the passages between them.

The beach in the Maldives is in most places formed almost entirely of carbonate of lime formations. Near villages, where much organic matter is present—from the soaking of coconut husks for coir on the reef-flat, etc.—and in the more enclosed parts of Addu lagoon no rock

occurs on the beaches. In Ceylon, where silica is always met with to a very considerable extent in some form or other in the beaches, my examination—extending round more than the half of the coast-line of that island—failed to find any typical formation of beach sandstone or indeed any trace of formation at all, except where the land above was of coral origin. In many parts the other conditions were perhaps not favourable, but in others looked eminently so. In any case the presence of even 5 per cent. of silica seemed to prevent any extensive building up of the sand of the beach into layers and terraces, typical of the appearance of the beach rock on coral islands. At Rotuma off Noatau, Oinafa and Pepji[1], where a typical formation exists, the beach was built up of almost entirely the same constituents as those which form the shores in the Maldives, the land in Rotuma for some distance behind the beach being in the above positions of coral formation.

Even the finest textured specimens of the sandstone show their constitution to the unaided eye. Of the very numerous pieces, which I broke off, none were in any way homogeneous, but all could be clearly seen to have been formed of sand grains of varying size. Where the sand was of extreme fineness, no rock was ever found. Minikoi has near the village on the lagoon side, where the conditions appear in many places exceedingly favourable for the formation of the rock, such a sand on its beach, but there is no trace of any consolidation into rock. Along the west side of Hulule, the sand is perhaps a trifle coarser but there is no sandstone except near the south point, round which coarser material is swept up on to the beach. Of coarseness there is no limit, the rock sometimes consisting of pebbles with the interstices filled in by sand. Indeed, it is only essential that there shall be such an amount of the latter that the surface of the beach is smooth, all the interspaces being filled in by the sand. The coarsest material on a beach is naturally found at its base, and in correspondence the sandstone usually increases in fineness, the higher it lies above the low tide level.

The beach sandstone is everywhere in the Maldives perfectly distinct from the raised rock of the islands, which is a submarine formation differing radically in its constitution. Both rocks, if in the same position, *i.e.* on the beach, would be affected by the same conditions, and might hence in external appearance resemble one another. The structure of the raised rocks has already been dealt with (pp. 35, 162, etc.), but it cannot be too strongly emphasised that the formation of this sandstone can only take place on the beach and between tide-marks. Its constituents show all the characteristics of such a formation, being much broken, angles rounded and surfaces pitted. Among them may be recognised pieces of coral of all the kinds found on the reefs or in the raised rock, but branching species especially of the genus *Pocillopora* are by far the most abundant. Small Molluscan shells and fragments of shell are common. Bits of nullipore, leaves of *Halimeda* and similar algae, spines and ossifications of Echinoderms, Crustacean remains and shells of Foraminifera make up the residue. The only constituents, not of lime formation, sometimes found are more or less decomposed fragments of pumice and sponge spicules and remains, but all these are relatively scarce, and do not in the Maldives form together more than ·1 per cent. of the total analysis. For the constitution of the rock, however, its mode of formation and its method of occurrence may best be considered.

The sand rock presents in its typical development on any beach a series of sloping terraces, separated from one another by steps. These terraces slope at the angle of the dip of the beach or slightly less, and the step from one to the other is about 5 inches and extends

[1] *Vide* "The Geology of Rotuma," *Q. J. Geo. Soc.* vol. LIV. pp. 1—11 (1898) and "The Coral Reefs of Funafuti, Rotuma, etc." *loc. cit.* pp. 438—44 (1898).

at right angles to the slope. The appearance would hence be that of immense stone slabs, all duly squared and laid on one another against a sloping bank. Sometimes there is as it were a single slab, sometimes 9 or 10 apparently on top of one another. Often there are two or more lines of such masses in a beach, each of one or more terraces, separated by hollowed out sandy areas, and yet perhaps more often a single line at the base of the beach from the half tide to the low water mark. Where the beach is steep or ends in a cliff, there may perchance be as at Boni-Kodi, Minikoi (p. 32) an induration of the sand of that cliff, but marked areas are only found on the shore, where the slope does not exceed 10°, and the beach consequently is of considerable breadth.

The varying conditions can of course best be seen by definite instances in different atolls, which will be found in Appendix B. to this paper. The greater part of the evidence also that any beach, where such formation is going on, is being washed away rather than growing outwards on its reef must likewise be sought in the same place. It is, however, clear from the consideration of the mode of formation of the sandstone that such must really be the case.

The first appearance of the rock on different beaches varies considerably. It commonly commences as a single broad line at the base of the beach, where it passes into the sand or reef flat. Such a layer merges into the sand of the beach above and into that of the flat below. Usually its rock is very soft, and can be easily dug out by a hammer or crowbar. It does not, however, remain long in this condition. If the beach is growing outwards on the reef, it becomes covered up with sand, and can only be traced as a slightly more consolidated layer in the sand of the island. More often the waves overtop the layer, and the sand above it is washed out, or the sand above may be removed by the wind. The layer on the face of the beach has now become a definite terrace.

When the sand above the layer has been removed to a depth of about 5 or 6 inches from the face of the beach, the first layer more or less protects the beach from further encroachment, and a fresh layer commences to form. By this means 3 or 4 layers may be found on a beach, the lowest merging gradually into the sand of the flat and the highest almost reaching the high water mark. The water after every wave, that runs up the shore, has somehow to reach the sea again. It naturally is hindered by each layer, along the top of which it flows to make its escape at the lowest point. Its action here is twofold, firstly in wearing away—partially by friction and partially by solution—the top of any layer, thus reducing it greatly in breadth, and secondly in undermining the layer, forming natural crevices by which the water joins the sea again. By this means more and more layers may be formed, in one place on the beach at Duravandu, South Mahlos (Fig. 75), seven having been thus fashioned. The water in its escape off the beach consolidates the sand under the top layer of stone, and the second layer accordingly may be traced under the first. In a section owing to this action all or most of the layers may be perceived, each layer being less consolidated than the one above it, until about the third or fourth merges into the sand of the island.

The natives are thoroughly well aware of the second or undermining action of the sea, and use it largely for obtaining their building material. A firmly consolidated layer is chosen, and, where it immediately overlies the layer beneath, its top is hollowed out so that the water may find a resting-place. When in a year or two the layer has become more or less undermined, a series of cross-cuts is made with the result that in another year the whole of the top layer can be wedged off in a series of slabs. In one of the beaches of the island of Male this action even on coral rock was clearly seen in a square about 4½ feet across, cut

FIG. 1. Beach Sandstone to NE. of Turadu Island, S. Mahlos Atoll.

FIG. 2. Quarrying coral rock at Male Island.

To face p. 344

FIG. 1. Sandy Beach to SE. of Hulule Island, Male Atoll.

FIG. 2. Elevated mass of coral rock on the sand flat to east of Hulule Island, Male Atoll.

To face p. 344.

in the beach, 5 to 6 inches deep, with a gutter for the water to escape (Plate XVI.). Whether the rock was in this instance part of a raised reef or of other formation was uncertain. It was of great hardness, largely formed of coral masses, worn quite smooth by the waves. According to the workmen's account, 4 to 5 years would be required in this case for the freeing of the slab. If this be so, the undermining action on sandstone masses, that constantly occurs in nature, must be a very rapid one.

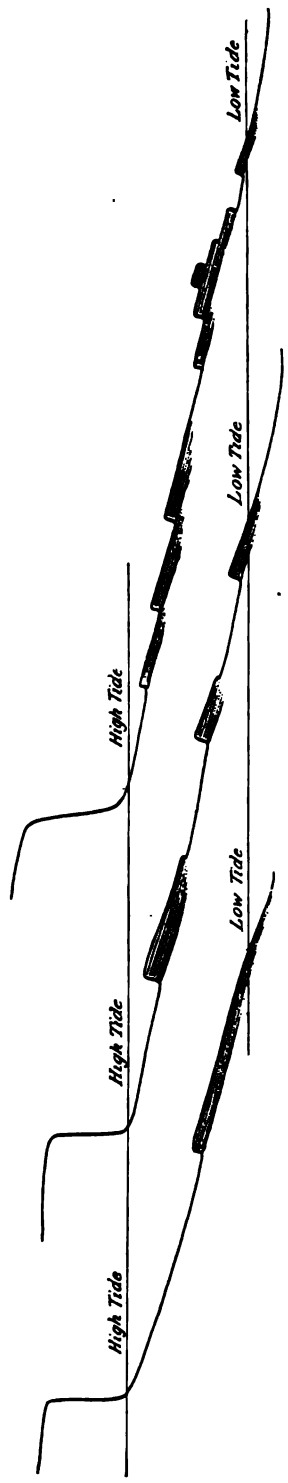

FIG. 75. Three sections of the beach to the south and south-west of Duravandu, S. Mahlos, showing the existing formations of beach sandstone (shaded). (*The vertical scale is double the horizontal.*)

When 4 or 5 terraces, extending from the low to the high water mark, have been formed, the further action by the sea may make no change in the surface appearance of the beach. The lowest and hence outermost line of slabs may be undermined and gradually broken off, but at the same time all the terraces are slowly being eroded away at their upper ends. A fresh terrace will accordingly always be forming just below the high tide mark. Should a cyclone resulting in an especially high sea arise, a considerable quantity of sand might be removed from the beach even above the top terrace. When the sea has thus once made a lodgement, its action tends to go on, resulting in a considerable hollowing out. So long as the washing away by the sea is extensive, no fresh sandstone can form on the beach. Nevertheless, a state almost of equilibrium is bound sooner or later to be reached, and will in most places then result in a fresh formation of rock.

The same conditions may repeat themselves, and the beach may hence come to have not one but a series of terraced masses with sand or water between each. In one part of the shore of Duravandu (Fig. 75), already alluded to in this connection, there are three such series on the beach. The lowest is 18 inches high above the low tide limit by 7 feet broad, and lies almost on the reef-flat; it has the remains of three terraces, and above steps down almost to the low water level again. The top of the second is 37 inches and that of the third 53 inches above the same mark. Above the latter the beach has, where it passes into the land, a distinct cliff, showing that it is still evidently washing away. A fresh series of terraces will probably sooner or later result in this manner. The differences in the height of the three series of masses above the low water level are evidently due to the action of the sea in tearing off and eroding the rock. A further complication is seen to the north-east of Turadu, S. Mahlos (Plate XVI.), where there are close together on the sand flat the remains of four lines of the rock, while at the base of the beach behind a fifth is now forming on the shore. To the south of the same island the washing away of the beach has been more rapid, resulting in two lines running out from the shore for about 140 and

300 feet on to the reef, as well as the remains of two series almost parallel to the beach at distances of 270 and 530 feet from the same.

The action, which forms the rock, is quite clear and requires little comment or explanation. The sea twice in the 24 hours covers and recedes from the beach. In a tropical region the sand may be said to be twice wetted and dried. In the latter process the salts in the sea-water are deposited on the sand grains. Some are at once redissolved on the tide again covering the beach, but the carbonates and the sulphate of calcium largely remain, in course of time filling up the interstices between the sand grains and binding them together. The sulphate of calcium later becomes largely replaced by the less soluble carbonate, a rock being ultimately formed of almost pure carbonate of lime. The rock is naturally built from the surface downwards, the drying up and fresh wetting by the sea being mainly superficial. The thickness of the layers, 5 or 6 inches in the Maldives, probably represents the mean depth to which the drying up of the surface is effective at low tide. That the sand must be formed necessarily in the first place of almost pure carbonate of lime remains is probably due to the more powerful attraction that bodies of the same or like constitution have on one another together with the restriction of the variety of the crystalline forms that would occur in the beach[1].

From the consideration of the foregoing account of the beach sandstone it will be obvious that almost any conceivable complication may arise in its appearance and distribution off any island that may be washing away. In nearly all cases the slope of any mass is that of the beach, of which it originally formed a part. The masses in course of time become more and more indurated with carbonate of lime and of great density and hardness. Where the beach is washed away and they lie on the flat, the terrace arrangement may disappear, and they will then become separate, long, irregular blocks, more or less rounded at the top. In this state they resist the action of the sea even more than the coral conglomerate, and where all remains of the latter may be lost these masses often are left. It is obvious then that from the study of such masses off any island or on any reef the former extent and contour of the land may be deduced with considerable certainty. The erosion of land in the Maldives, the formation of flats at about the low tide level by the washing away of the land and the hollowing out of such flats to form first pools, then velu or definite lagoons, may absolutely be traced. The facts speak for themselves, and—if my views as to the formation of this rock be correct, of which I can have no doubt—I claim to give indubitable proof that the conceptions of Murray as to the formation of lagoons and my own opinions, enunciated in Chapter VII. of this paper, rest on a firm and correct basis.

[1] The skeletons of the organisms that form the sand are generally of calcite or arragonite. Most of the deposit of calcium carbonate is in the first place in the amorphous state, subsequently metamorphosing to the crystalline form of the remains of the organism nearest to it. This deposition of amorphous material may be due to the constant presence of a small trace of organic matter, hindering crystallisation.

The reason why a relatively small amount of organic matter should prevent the formation of beach sandstone, as in the instances mentioned above (p. 343), is not however quite clear.

It is interesting to notice that the natives of Suvadiva make use of this indurating action of the tidal waters to harden the corals of which they make gravestones. The coral—generally a mass of *Porites arenosa*—is roughly squared and then deposited for a year on the beach between tide marks so that the pores may be filled up, the whole then wearing much better when placed in position.

(*To be continued.*)

CEPHALOCHORDA.

I. SYSTEMATIC AND ANATOMICAL ACCOUNT.

By C. Forster Cooper, B.A., *Trinity College, Cambridge.*

(With Plate XVIII. and Text-figures 76—89.)

II. NOTE ON MERISTIC VARIATION IN THE GROUP.

By R. C. Punnett, M.A., *Fellow of Gonville and Caius College, and Demonstrator of Comparative Anatomy in the University of Cambridge.*

I. SYSTEMATIC AND ANATOMICAL ACCOUNT (By C. Forster Cooper).

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The following is an account of two species of *Amphioxus* from the Maldive region, one of which, viz. *Heteropleuron maldivense*, is new and related to *H. bassanum*. An account is also given of some larvae, the adults of which are uncertain.

I take this opportunity of thanking Mr Adam Sedgwick for permission to work in his laboratory, and for the great interest he has taken in the work. I am also indebted to Mr J. J. Lister, Major Alcock, Mr R. C. Punnett and Mr Crossland for specimens from other localities in the Indian Ocean. I would also thank Mr A. E. Shipley for the encouragement he has at all times shewn me.

1. ASYMMETRON LUCAYANUM (Andrews). Pl. XVIII. fig. 1.

This species of Cephalochorda is by far the most abundant in the Maldives, occurring roughly in the proportion of 100 to 1 of the only other form found (*Heteropleuron maldivense*). It seems to be identical in almost every particular with the form described by Andrews from the Bahamas[1].

The only point in which the Maldivan and W. Indian forms consistently differ from one another is in their size. The average length of the Maldivan specimens is 23 mm., the extremes being 18 and 30 mm., thus being nearly double the length of the Bahama specimens which Andrews found to average 13 mm. In spite of this difference the average myotome formula for the two forms remains practically the same, the mode in each case being 66 myotomes, *i.e.* 44 from the head to the atriopore, 9 from the atriopore to the anus, and 13 from the anus to the tail.

The most prominent external feature of the species is the long caudal extremity which at once differentiates it from all other known forms of Cephalochorda. There is a narrow rostral fin round the anterior end of the notochord, which projects some 2 mm. beyond the end of the first myotome. This is continued dorsally as a low fin running the whole length of the body to the tip of the caudal extremity. Owing to the taper of the body the fin is rather deeper for the last fifteen myotomes (*i.e.* from about the level of the anus to the caudal extremity). From the last myotome to the tip of the tail it narrows down to a point.

The ventral fin is a continuation of the right metapleural fold, and like the dorsal fin it also broadens out for the last fifteen myotomes, though somewhat deeper than the last named. It bends up suddenly at the last myotome, and becomes the ventral part of the narrow tapering caudal fin. The depth of the dorsal and ventral halves of the latter fin is the same.

In the dorsal fin from about the 17th to the 32nd myotome there are fin-ray spaces containing small blocks of cartilage, the fin rays. These begin anteriorly as small irregular blocks, which gradually increase in size and become more regular, averaging two to a myotome; towards the tail they again decrease in size. There is, however, much variation in different specimens both in the number and size of the fin rays. The ventral fin possesses neither fin rays nor fin-ray spaces.

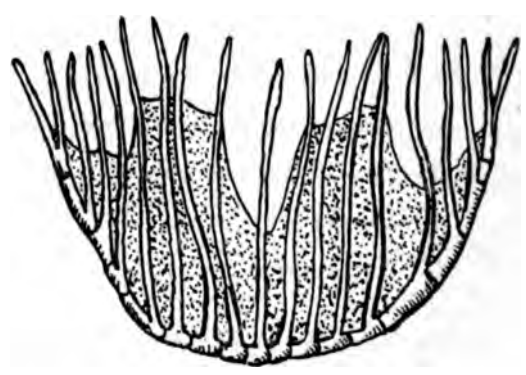


Fig. 76. Buccal cirri of *Asymmetron lucayanum*.

In comparison with *Amphioxus lanceolatus* the general shape of the species is long, thin, and somewhat narrow from side to side. The metapleural folds end short of the buccal hood, and do not in any way connect up with it. The buccal hood is long and shovel-shaped, but not very deep. The buccal cirri number 19, and are divided into two groups on each side of a median unpaired tentacle. The outer group on either side consists of five tentacles joined together by a low membrane, whilst each inner group possesses four tentacles connected by a high membrane which reaches fully three-quarters of the way up the cirri (Fig. 76).

[1] *Stud. Johns Hopkins Biol. Lab.* vol. v.

The tentacles are smooth and without any sensory patches.

The preoral pit is large, and in structure is similar to that of *A. lanceolatus*. The blood vessel running with it breaks up into a glomerulus, in which the vessels are less in number but of a larger sectional area than usually obtains in the European species. In this point there is some variation, certain of the specimens approaching more nearly to the former type, others more to the type as described by Andrews.

The "Räderorgan" is large and well formed. It consists of a large dorsi-lateral arm on each side of the buccal hood, and thin secondary arms with smaller loops in between. The dorsal arm of the left side is longer than that of the right, and connects up with the preoral pit. The whole organ forms a ring of tissue round the base of the buccal hood, the arms being pulled out along its sides.

The mouth and velum underlie the apex of the eleventh myotome. There are eight velar tentacles. The pharynx stretches between the level of the apices of the 10th to the 45th myotome, thus occupying a space a little over half the total length of the body. Both mouth and pharynx as well as the alimentary canal are similar in structure to the corresponding organs in *A. lanceolatus*. The skeletal bars of the gills are normal in general plan, but the synapticulae joining the bars together are only three in number and very slender.

The nervous system presents no great peculiarities, the most noticeable feature being the absence of the olfactory pit, no traces of which could be found. The nerve cord stretches to the tip of the caudal extremity as a very fine thread. Special nerves are given off only in the region of the myotomes. Beyond this point, *i.e.* in the caudal extremity, no nerves arise from the nerve cord.

The excretory system consists solely of patches of epithelium on the floor of the atrial cavity. No trace of nephridia on the gills could be seen, nor could Lankester's brown funnels be traced. Andrews was similarly unable to find these in the Bahama form, so that their non-existence seems certain.

The circulatory system (of which only the main vessels were traced) is similar to that of *A. lanceolatus*.

The gonads are placed on the right epipleur, and are twenty-nine in number, lying from the 14th or 15th to the 43rd or 44th myotomes. The first few gonads are small. They present a gradual increase in size till the centre of the series is reached, after which they again begin to decrease, the last few gonads being of the same size as the first. The period of sexual maturity seems to bear no relation to the size of the animal. Very small specimens were found with well developed gonads (always 29 in number), while some of the largest obtained, measuring 30 mm., had them very little or not at all developed.

2. HETEROPLEURON MALDIVENSE. Pl. XVIII. fig. 2.

This species is by no means common in the Maldive Islands, only four specimens being obtained from Mahlosmadulu Atoll. None were found in the lagoon of the Island of Minikoi, and since Mr Gardiner searched this locality extremely carefully during the months of June, July, August and September without finding either adults or larvae, it may be concluded that it does not occur there.

Heteropleuron maldivense more closely resembles *H. bassanum* (Günther) from Bass' Straits, Australia, than any other species in the genus. It is somewhat similar to this species as figured by Kirkaldy[1] but differs in the shape of the fins, in being of much smaller size, and in some other small particulars.

As there is no account of the anatomy of *H. bassanum*, it is not possible to say whether that species shares the peculiarities of the form here described.

The largest specimen obtained measured 2 cm.[2] (*H. bassanum* averages 4·3 cm., Kirkaldy). The depth is rather large in proportion to the length (Plate XVIII. fig. 2). The dorsal fin is rather narrow posteriorly but becomes broader as it approaches the head, being at its greatest depth about one-sixth of the total depth of the body. It runs forward with only a very slight notch into the moderately-sized rostral fin. It is throughout its length provided with fin-ray spaces and long fin rays closely crowded together. These number between three and four to the myotome, the rays becoming shorter and slightly broader posteriorly.

The rostral fin runs forward for a short way and then bends round the snout, and continues ventrally for a short distance until it finally joins the buccal hood on the left side. The ventral fin has the same depth as the dorsal fin in the corresponding region; it is a continuation of the right metapleural fold, and has single fin-rays and fin-ray spaces, differing in this respect from *H. bassanum* where they are paired.

The caudal fin is lance-shaped and, in comparison with *Amphioxus lanceolatus*, rather narrow. The ventral half is a little deeper than the dorsal. Both the superior and inferior angles are very slight.

The myotome formulae of the four specimens were

	Number of myotomes from		
Total No. of myotomes	Head to atriopore	Atriopore to anus	Anus to tip of tail
73	45	16	12
74	45	16	13
72	46	16	12
75	46	16	13

The average given by Kirkaldy for *H. bassanum* is

75	45	16	14

Anatomy. This species on the whole is similar to *Amphioxus lanceolatus* in its larger features, but presents some minor differences. The preoral pit is rather small compared with that of *A. lanceolatus*, running halfway up the side of the notochord (Fig. 77). Further back it comes to lie high up on the left wall of the buccal hood (Fig. 78). Except at the point where it runs up at the side of the notochord it is very shallow. The blood vessel, which runs above it, is divided at most into two or three vessels, instead of breaking up into a glomerulus as in *A. lanceolatus*.

The "Räderorgan" consists of one median dorsal loop, in the left side of which is placed the preoral pit. Each wing of this loop runs back towards the velum, and then forward again to form the four or more secondary loops on the sides of the buccal hood. The two epithelial tracts join on the base of the velum and complete the ring.

[1] *Q. J. M. S.* vol. XXXVII. (1895).

[2] Table II. in Mr Punnett's account of the Meristic Variation.

The buccal hood is chiefly noticeable for the great extent and thickness of its gelatinous walls, a feature also of the whole front part of the animal.

A section just behind the region, where the rostral fin runs into the apex of the buccal hood, shews the great general development of the gelatinous tissue, when compared with the area occupied by the muscles, &c. (Fig. 79). It will be noticed that in the section figured, the tips of the buccal cirri have been cut through at this level.

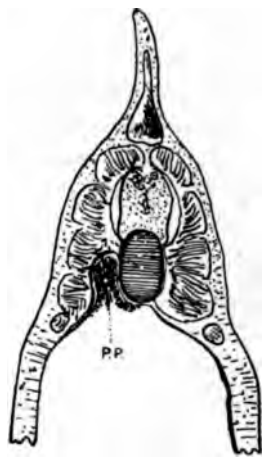


Fig. 77.

Fig. 78.

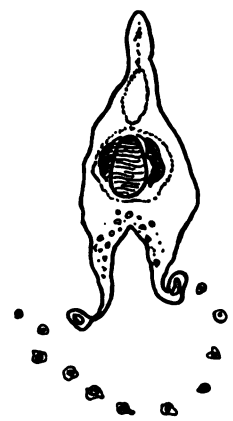


Fig. 79.

Fig. 77. *Heteropleuron maldivense.* Section through the middle of the preoral pit (*P.P.*).
Fig. 78. *Heteropleuron maldivense.* Section through the end of the preoral pit, showing the great development of the hood.
Fig. 79. *Heteropleuron maldivense.* Section through the anterior end of the head immediately behind the rostral fin. The buccal cirri are cut through near their free ends.

The side walls of the hood as they proceed backwards gradually become deeper, and at their lower edges appears the ring of cartilage from which the buccal cirri spring. The hood is of a broad shovel-shape, and the buccal ring thus has a V-shape with a pointed apex and rounded sides. The cirri are 23 in number and are webbed half-way up their extent except the last four on each side, which are small and free. Sections at different levels in front of the velum shew the development of the hood (Figs. 78—80). In the front part of the hood are a number of lymph spaces which traverse the gelatinous substance, and frequently anastomose with one another.

The gill slits in general structure are precisely similar to those of *A. lanceolatus* as are also the branchial skeleton and endostyle. In one specimen a primary bar was found, possessing two skeletal rods (Fig. 81), joined together at their base. They almost directly separated and

ran up side by side, and there was only one division of the coelom as figured. According to Benham this is a fairly common variation in *Amphioxus lanceolatus*[1].

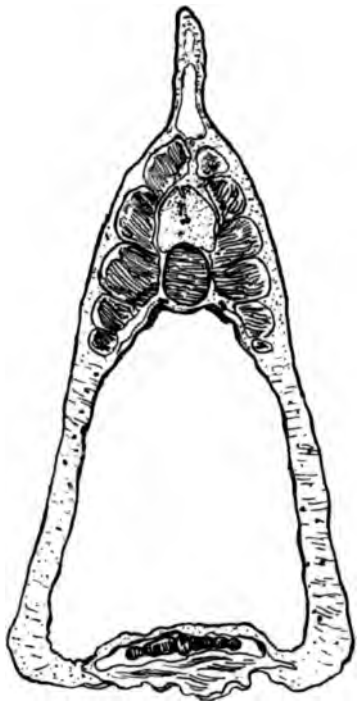


FIG. 80. *Heteropleuron maldivense*. Section just in front of the velum. The origin of the buccal cirri is seen at the bottom.

The alimentary canal from the region of the atriopore stretches through 21 myotomes to the anus. The liver caecum is comparatively short, running through only nine myotomes.

The excretory organs are of the usual type. The epithelial patches on the floor of the atrium are numerous and well-marked. Nephridia on the gills could also as a rule be seen. They have the usual structure as described by Goodrich[2], and their atrial openings were distinctly observed. Lankester's brown funnels do not occur.

The circulatory and nervous systems both conform to the usual type, but in the latter no olfactory pit was found. Only the gross anatomy of these organs could be made out, but as far as the histology was observed, there is no difference between them and the same organs described for *A. lanceolatus*.

Since working out this form I have received a large number of specimens of *H. maldivense* from Mr Crossland, who obtained them at Zanzibar. I have been thus enabled to make a fuller list of measurements, which shew that the size of the animal may be larger than the Maldivan specimens led me to expect, although the average remains about the same. These measurements will be found in Table II. p. 363 of Mr Punnett's "Note on Meristic Variation in the Group." Unfortunately the specimens were not very well preserved. The gonads had in some cases broken away, and in others, marked with a note of interrogation (?), their position was a little doubtful.

To sum up the specific differences between this form and *H. bassanum*. The myotome formula is on average 73 in all, 45 from the head to the atriopore, 16 from the atriopore to the anus, and 12 from the anus to the tail; while the total number in *H. bassanum* is nearly the same, *i.e.* 75, there is a constant difference of two myotomes in the caudal region, *H. bassanum* having 14. The dorsal fin is much deeper than in *bassanum*, the rostral fin is a little smaller and the notch is very much less marked. The preoral cirri number 23 as against 33, and the ventral fin is without the paired fin rays and spaces[3].

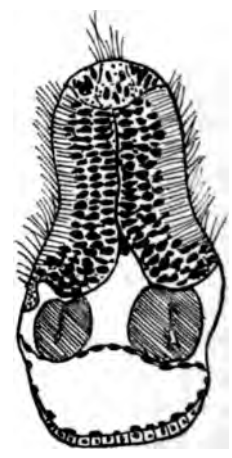


FIG. 81. *Heteropleuron maldivense*. Abnormal double gill bar.

3. BRANCHIOSTOMUM PELAGICUM.

Through the kindness of Mr J. J. Lister I have been enabled to examine a specimen of an *Amphioxus*, which was obtained by him in the year 1888 in latitude 21° 16′ S. and longitude 80° 50′ E. *i.e.* in the

[1] *Quart. Journ. Mic. Sci.* 1893, vol. XXXV. Part 1.

[2] *Quart. Journ. Mic. Sci.* 1900, vol. XVIII. Part 4.

[3] Dr Benham (*Q. J. M. S.* vol. XLIV. p. 276) states that double fin rays do not occur in the ventral fin of *H. bassanum*. Kirkaldy (*loc. cit.*), however, avows that her specimens were in good condition, so that a mistake could hardly have been made. Variation in this respect may occur.

centre of the Indian Ocean about half-way between Madagascar and Australia. The depth at which it was taken cannot be stated with any certainty, as it came up in a dredge which had been working in 800 fathoms. It may thus have been taken on the bottom or enclosed in the net as it was hauled up.

The form on examination proves to be a specimen of *B. pelagicum*, the only other known example of which was taken by the Challenger in 1875 in the open Pacific, and which was described by Günther in the Challenger Report on the pelagic fishes. The specimen considered here was unfortunately in so bad a condition, both externally and internally, that it was impossible to work out its internal anatomy, either by sections or by mounting whole. The Challenger specimen was almost equally bad, so that until fresh and better preserved specimens are obtained, we must remain ignorant of its organisation, which should prove interesting.

FIG. 82. *Branchiostomum pelagicum*. View of the preserved specimen. The branchial region is seen on the under side to the left.

In length the specimen is 21 mm. and it possesses 60 myotomes (the exact number is uncertain owing to decay), while the Challenger specimen had 67 myotomes. The tail fin is broad and lance-shaped, the dorsal and ventral halves being equal (Fig. 82). For the size of the animal it is extraordinarily well-developed, a condition which lends colour to the view that it is a true pelagic organism. A very narrow dorsal fin runs forward from the tail to the head, and an equally narrow ventral fin is present, the precise length of which could not be made out.

The shape of the head is peculiar, being tapered and ending in a pronounced snout. No trace of buccal cirri could be seen either when viewed sideways or when cut into sections. It would indeed seem that the absence of buccal skeleton is a real character, and not due to maceration or loss, none being found in the Challenger specimen. The structure of the branchial region could not be well seen, owing to the bad preservation of the inner parts of my specimen. It appeared however to be peculiarly small in extent, and quite similar to Günther's figure of the Challenger specimen.

4. PELAGIC LARVAE. Pl. XVIII. figs. 3—6.

Although larvae of *Amphioxus* were throughout found to be far from common, about a dozen were taken in the south of Miladumadulu Atoll and in Fadifolu Atoll, during rough and stormy weather in the last fortnight of December, 1899. They were caught at sundry depths from 8 to 20 fathoms. All were secured during the night in the channels leading from the open sea to the atoll lagoons by hanging tow-nets at different depths over the stern of our schooner, in such a manner as to keep them well swung out by the currents, which drive the various forms of the plankton into them.

It cannot be ascertained with any certainty whether the larvae are those of *Asymmetron*, *Heteropleuron* or of some other form the adult of which we did not obtain. There are many reasons, derived from the anatomy of these larvae, why they should not belong to *Asymmetron*, in spite of the fact that this form is present in our collections in the proportion of one hundred or more to one of *H. maldivense* (the only other form found).

The larvae evidently all belong to one and the same species, and, although they do not form a series extending over any considerable period of development, seem to possess some features worth describing. They are all in nearly the same stage, but owing to the unusual nature of their gill clefts, cannot be compared at all closely in point of age with the well-defined stages in the larval history of *Amphioxus lanceolatus* as described by Willey[1].

In shape and external appearance the larvae are not unlike those of *A. lanceolatus* when both are viewed from the side (Pl. XVIII. figs. 3 and 4). There is a moderate-sized dorsal fin extending from the tail to about the level of the end of the pharynx, in front narrowing down to half its previous width, and continuing forward with the same breadth to the front end of the body. The tail fin is lance-shaped, the dorsal and ventral halves being of precisely the same depth. The ventral fin is a continuation of the tail fin, and is similar to, but slightly deeper than, the corresponding part of the dorsal fin. It extends rather further forward than the broad part of the latter, and passes to the right side of the anus.

The youngest larva in the collection measures 5·75 mm. in length and 1·5 mm. in depth (Pl. XVIII. fig. 3), and possesses 60 myotomes. Its external form is as described above, and it has 14 gill slits on the ventral side open to the exterior throughout. A stout notochord of typical structure runs throughout the body from the tip of the snout to the extreme end of the tail.

The central nervous system commences in the second myotome, and extends to the extreme end of the tail, the last part being very slender. The eye spot (Fig. 83) consists of a round mass of black pigment situated on the upper wall of the brain cavity at a little distance from its front end. It is of comparatively large size, and projects into the lumen of the cavity in such a manner as to almost fill it. The eye thus differs a little in position and shape from that found in *A. lanceolatus*, where it is a conical cap of pigment placed on the front end of the brain. The anterior dorsal nerve is very conspicuous, and the spinal nerves are given off in the usual manner. The olfactory pit is placed almost immediately behind the eye spot. Except in being of a rather smaller size it in no way differs from that of *A. lanceolatus*. The presence of this structure proves that these larvae cannot be considered to be the larvae of the Maldive *Asymmetron*, in which it does not occur.

[1] Willey, *Amphioxus and the Ancestry of the Vertebrates.*

The preoral pit is at this stage large and well-formed. At its extreme anterior end it originates as a small knob of tissue projecting into the head cavity (Fig. 84 *PP.*). In this an invagination commences, which rapidly increases in size as it proceeds backwards. On the dorsal side of the pit appears the preoral sense organ (Fig. 85 *P.S.O.*), a ciliated gutter which after proceeding backwards for a short way ends blindly in front of a forward prolongation of the pharyngeal region, the lumen of which opens directly behind the groove (Fig. 86). As shewn in the figure there are two of these blind caeca running up from the pharyngeal region, one dorsal and one ventral to the preoral pit; their walls at the ends are glandular.

The club-shaped gland begins a little in front of the larval mouth opening. It is similar in shape to that described for *A. lanceolatus*, and has the opening in the dorsal arm—by which its cavity is put in connection with that of the pharynx—well-marked. No opening, however, could be found in the lower arm connecting it with the exterior as described by Willey[1]. In this early stage the endostyle is not very far advanced. It shows only as a patch of modified epithelium lying immediately in front of the club-shaped gland.

Fig. 83.

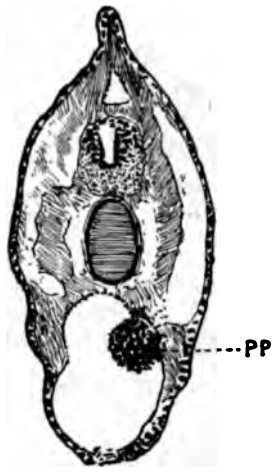


Fig. 84.

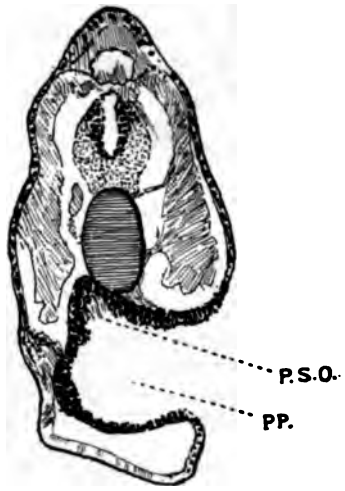


Fig. 85.

Fig. 83. Larva. Transverse section passing through the eye.
Fig. 84. Larva. Section through the anterior part of the preoral pit (*PP*).
Fig. 85. Larva. Section through the middle and largest part of the preoral pit (*PP*). The preoral sense organ (*P.S.O.*) lies dorsally and to the left of the notochord.

The mouth is a small elongated slit lying on the left side about one-third of the way up from the ventral side. The obscure organ termed Hatschek's nephridium lies on the left side just under the notochord and runs into the pharynx.

The first gill slit opens under the mouth and a little to the left of the mid-ventral line (Fig. 87 *G.S.I.*). The next two slits also lie somewhat to the same side gradually approaching the mid-ventral line, in which the rest are placed. The right metapleural fold arises at a more forward level than the left, which starts from the hind corner of the mouth between the second and third gill slits. It rapidly increases in size until it equals its fellow of the right side. Between these folds the gill slits occupy a mid-ventral position.

[1] Willey, *loc. cit.*

On each bridge of tissue between the gill slits the branchial epithelium projects as a mass of large columnar cells with darkly staining nuclei (Fig. 88). Many sections, but by no means all, give an appearance of having the branchial epithelium split into two (Fig. 89)[1]. The latter extends alternately down each side of a slit, so that every slit has the branchial epithelium

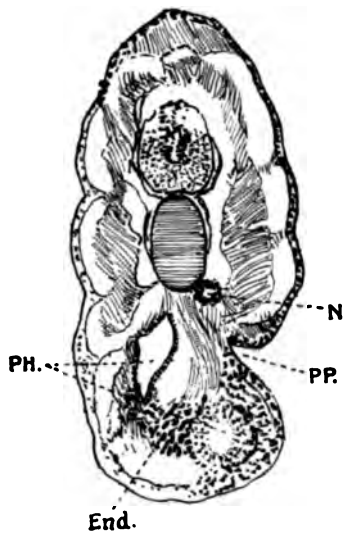


Fig. 86.

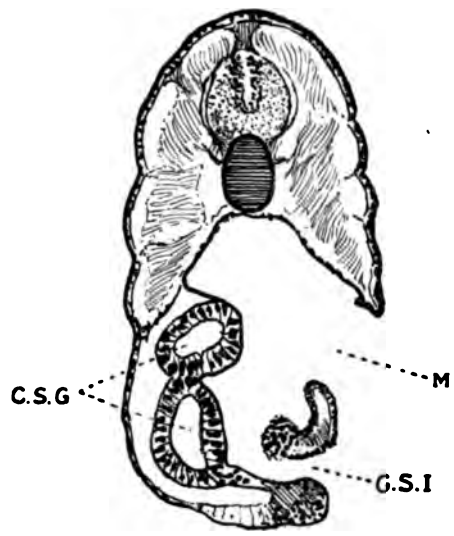


Fig. 87.

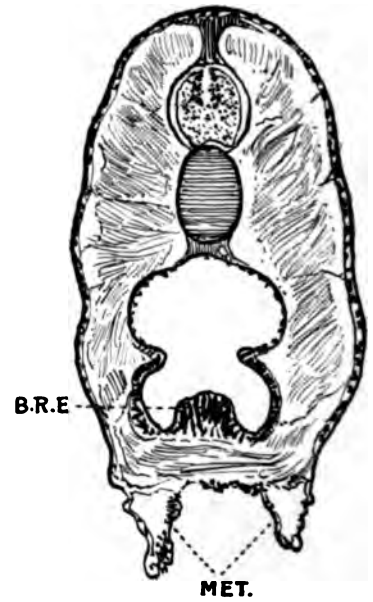


Fig. 88.

Fig. 86. Larva. Section through the extreme posterior end of the preoral pit (*PP.*), showing Hatschek's nephridium (*N*), the commencing formation of the endostyle (*End.*) and the two prolongations of the pharynx (*PH.*).

Fig. 87. Larva. Transverse section passing through the mouth (*M*) and first gill slit (*G.S.I.*). The two arms of the club-shaped gland (*C.S.G.*) are also shown.

Fig. 88. Larva. Section through a part between two gill slits showing the metapleural folds (*MET.*) and the branchial epithelium (*B.R.E.*).

on the opposite side to the one preceding and following it. The meaning of this is not clear, and can only be solved satisfactorily by the examination of later stages.

Springing from the middle of the pharynx are the true hyper-pharyngeal bands. The left-hand band arises immediately behind the mouth, that on the right hand commencing directly behind the club-shaped gland. They both extend through the whole length of the pharynx, and die out at the beginning of the intestine. The latter itself is normal. The glandular patch in the rectum in all these larvae is very noticeable.

Fig. 89. Larva. Section to the right through a gill slit and to the left intermediate to two slits. The left section shows the appearance of splitting found occasionally in the branchial epithelium.

In a later stage (Pl. XVIII. figs. 4 and 5), also having 60 myotomes, various changes are found to have taken place. The endostyle has become fully formed, and has acquired all the essential histological features found in the adult. It still, however, lies in the larval

[1] I am unable to say whether this phenomenon has any real meaning, or is merely due to the combined effects of preservation and section cutting.

position, and has not yet taken up its permanent location on the ventral side of the pharynx, which shews that a certain amount of torsion still has to take place. It now extends over and beyond the club-shaped gland for some distance. The two arms of the latter organ have become histologically differentiated, the upper arm having a large lumen with tall glandular cells, the lower arm being drawn out into a tube with a small lumen and much smaller cells.

The preoral pit now leads right down to the front end of the larval mouth as a narrow gutter, open to the exterior throughout its whole length. The buccal hood has not yet begun to grow out.

In this larva the gill slits numbered 31. As in the younger form all the openings lie in a series one behind another in the mid-ventral line. Plate XVIII. fig. 5 shews the ventral view of this larva. The appearance of the slits in the mid-ventral line is curious, for the reason that the bridges between the openings are very long and narrow. Owing to this they have become much twisted, and their shape somewhat obscured. Their form can, nevertheless, be traced out, and it is seen that they have a somewhat rectangular shape. There is no sign of any crescent-shaped infolding to form a tongue bar. There is absolutely no trace of any secondary gill slits breaking through in the manner usually described—that is, on the right side and above the primary slits. Normally the secondary slits should shew, at their first origin, as six oval thickenings situated on a continuous ridge of tissue, in the right wall of the pharynx above the primary slits, and this should take place when the larva has fourteen primary slits fully formed. As has already been seen the first larva possessed the requisite number of primary slits without signs of the appearance of any secondary ones. Further, in the normal development, the formation of the secondary slits, after they have once started, is very quick, and the number of slits on each side becomes even. A certain number of primary slits close up and a stage with eight on each side is reached.

Indeed, the phenomena found in these larvae cannot be brought into any uniformity with the plan of *A. lanceolatus*. In none of the specimens obtained is there any sign of secondary gills, although possessing from 15 to 31 'primary' slits. It seems impossible that after such a late stage has been reached, the secondary slits should arise by perforation in the usual place, especially now that the metapleural folds have been well formed. What precisely does occur it is impossible to say owing to the lack of the later stages which only could throw light on the subject. For the same reason one cannot say whether any of the slits present close up as do some of the primary slits in the larva of *A. lanceolatus*.

Such evidence as there is, points to some different method of origin of the gills to that which is found in *A. lanceolatus*, the only species in which the full development has been thoroughly observed. There is no reason why all species should have precisely the same way of development, but unfortunately the facts here are hardly sufficient to warrant any deductions as to how the gills arise in the present peculiar form.

The fact that the larvae were taken right away from the grounds where the two Maldivan species of *Cephalochorda* were found, and also that they were taken in heavy weather close to the channels leading from the sea, makes it possible that they may be the larvae of some pelagic form, whose altered mode of life may account for the differences of larval growth mentioned above.

5. DISTRIBUTION AND HABITS OF THE MALDIVAN CEPHALOCHORDA.

1. *Asymmetron lucayanum.*

In the Atoll of Minikoi, which was very thoroughly searched by Mr Gardiner between the months of June and September, many specimens of this form were obtained. Their distribution in the atoll proved to be very local, and although many places at first sight seemed to be suitable they were restricted to practically one spot—viz. the Neru-Magu channel (*vide* Chart, Part I. page 28 of the present work), on the N.W. side of the atoll, which runs in across the sand-flat with a depth of about 2 fathoms. The sides of the channel were of sand and rather steep. The bottom was found to be of rock covered with a few inches of sand and studded with small growths of corals. It was in the shallow sand at the bottom of the channel that the specimens were found.

Very careful search in the sand at the S.W. part of Minikoi lagoon, which is covered by shallow water, revealed only one specimen, and none were found in any other part of the lagoon, except close to the channels from the sea. A few specimens were kept alive for several days in a basin covered with fine silk gauze and sunk in the lagoon. Their dislike to strong light, recorded by Andrews[1], was observed, and Mr Stanley Gardiner also informs me that they were never seen to lie on their sides on the surface of the sand as the European species commonly does.

The distribution in the Maldives is also local and peculiar, specimens often being found in small numbers at unexpected depths and places. A list of the localities and depths is here given.

(1) *Suvadiva Atoll.*

Two specimens were obtained from a hard bottom consisting of rough stony rubble with masses of weed and calcareous algae. 29—30 *f.* (*fathoms*).

(2) *Mahlosmadulu Atoll.*

A few specimens from coarse sand mixed with a little rubble, about 20 *f.*, near Turadu and Duravandu Islands: in the *velu* (lagoon) of the island of Berriamfuri several were secured off the sandy bottom, 3—4 *f.*

(3) *Fadifolu Atoll.*

Several were dredged from a bottom consisting of rough corals, weeds and sponges, in the channel to the north of Naifaro, 15 *f.*, and a few also from a hard bottom with weeds and a little sand, 23 *f.*, near the centre of the lagoon.

(4) *Miladumadulu Atoll.*

Two or three came from a large block of *Porites* which was dredged up, being found in sand which had collected in small quantities in the crevices of the coral, 20 *f.* Several were taken in the sand of the *velus* of the islands of Mafaro and Edufaro, 3 *f.* In Furnadu the shallow sand-flat (2—3 *feet*) between the islands of Furnadu and Farukolu, an area swept by strong tidal currents, yielded a number of specimens.

(5) *Male Atoll.*

In the island of Hulule, where a longer stay than usual was made, a large number of specimens were secured and their distribution was carefully studied. Five only were obtained

[1] *Loc. cit.*

in the *velu* which is a sandy area of considerable size and with an average depth of from 6 to 7 fathoms. Five specimens were also brought up from a depth of 25 fathoms off the west reef of the island, *i.e.* in the main lagoon of the atoll from a bottom of decaying rock and sand.

By far the largest number, however, came from a particular spot at the south end of the *velu*, just to the north of the north-west point of Hulule island. From this end of the island a sand spit runs out for a distance of some 70 yards, the greater part covered at low water. The sand at the end of this spit suddenly dips down into a channel which at low tide never had less than 4 feet of water in it. This channel was about 30 yards across its widest part and ran east and west at right angles to the length of the island. At the further end of the channel was another sand spit of about 50 yards breadth which gradually sank into the *velu*. A current at almost all states of the tide ran up or down the channel, often with considerable force, keeping the sand at the bottom and sides in a continual state of motion, and it was in this sand that *Asymmetron* was found to be most abundant. About two hundred were actually obtained, but any quantity could have been caught if desired. They were taken by wading out into the channel and dipping a sieve into the sand, a dozen or more being often caught in one lot.

It would thus appear that the chief and most favourable habitats are moderately shallow and sandy channels, as in this place, in Furnadu, and in the channel in Minikoi, the three places in which the greatest number were found. In all other places, where there was a greater depth and an absence of current and sand, only a few odd specimens were taken. There were several places visited in which the conditions seemed to be quite suitable for *Amphioxus* but in which no specimens were found. This was notably the case off Goidu in Goifurfehendu Atoll. The reason for this very local distribution is not easy to explain, but it was noticeable that wherever *Asymmetron* was abundant, other sand-living animals were absent or very scarce[1].

The distribution of this species from a larger point of view is interesting. Mr Crossland obtained a few in Zanzibar, but no other specimens are recorded from the Indian Ocean. The only other locality so far recorded is the Bahamas in the West Indies, where they were first obtained by Andrews.

2. *Heteropleuron maldivense.*

The number of specimens found in the Maldives is too small to admit of any deductions as to habitat. Three specimens were found in Mahlosmadulu in coarse sand at a depth of 20 fathoms, and one specimen in a channel into Fadifolu at a depth of 15 fathoms. Mr Crossland, who found a large number of this species in Zanzibar, informs me that they were taken on sandy bottoms at a depth of 7 to 8 fathoms.

The following *Cephalochorda* have now been recorded from the Indian Ocean:—

1. *Amphioxus belcheri* Gray. Madras, 6 fathoms, off "Seven Pagodas, Mahabili," dredged by Major Alcock; and Singapore, several larvae and a few adults. This species also occurs in Prince of Wales Island, Torres Straits and Borneo.

2. *Asymmetron lucayanum* Andrews. Maldive Islands, Minikoi and Zanzibar. The species is found also in the West Indies.

[1] In this connection it may be remarked that *Asymmetron* is a discriminate feeder. It lives on particles of vegetable matter, and does not swallow sand, as do many other sand-living organisms.

3. *Heteropleuron cinghalense* Kirkaldy. Coast of Ceylon.

4. *H. maldivense*, n. sp. Maldive Islands and Zanzibar.

5. *Dolichorhynchus indicus* Willey. "Black Pagoda," off the Orissa coast of India.

6. *Branchiostomum pelagicum* Günther. One specimen each from Indian and Pacific Oceans.

DESCRIPTION OF PLATE XVIII.

FIG. 1. *Asymmetron lucayanum.*

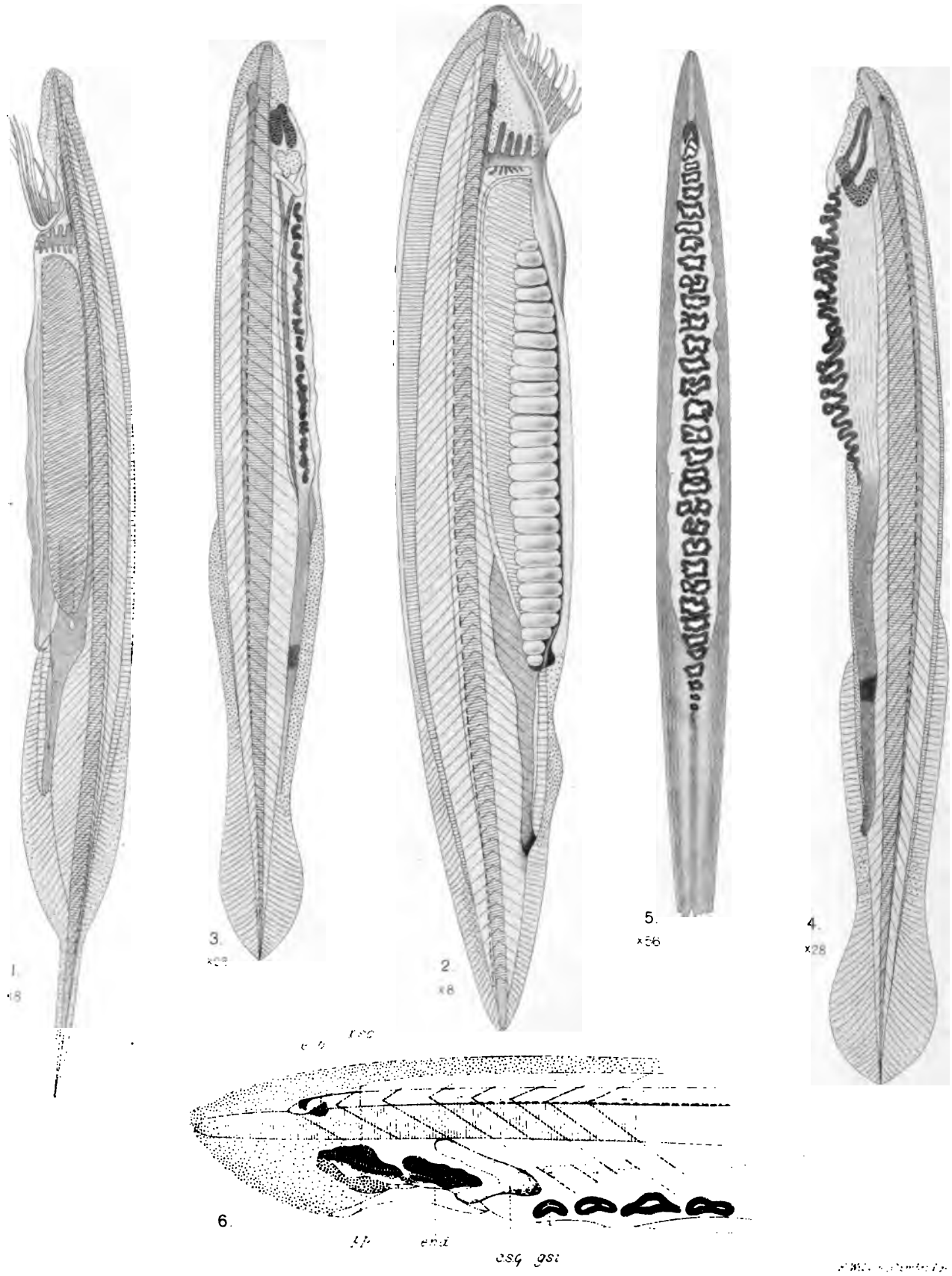
FIG. 2. *Heteropleuron maldivense.*

FIG. 3. Larva with 60 myotomes and 16 gill slits (length 5·75 mm.).

FIG. 4. An older larva with 61 myotomes and 31 gill slits (length 6·5 mm.).

FIG. 5. A ventral view of the above larva shewing the extent of gill slits in the ventral surface. The slits are seen to be of a roughly rectangular shape, the outlines being somewhat obscured by the twisting of the edges.

FIG. 6. Enlarged view of the head of Fig. 3. *e.* eye spot, *b.* brain, *p.p.* preoral pit, *p.s.o.* preoral sense organ, *end.* endostyle, *c.s.g.* club-shaped gland, *g.s.*1. first gill-slit.



Forster Cooper – Cephalochorda

II. NOTE ON MERISTIC VARIATION IN THE GROUP.

(By R. C. Punnett.)

The Cephalochorda are probably regarded by the majority of zoologists as a form of life which has remained comparatively unchanged during lengthy epochs of time. And although from the nature of the case direct palaeontological evidence is lacking, morphology would seem to support the view that the group is one of great antiquity. Moreover from the paucity of species in existence at the present day and from the similarity of their structure, the zoologist is led to conclude that the group has probably lost the power of extensive further differentiation and is, as it were, on the down grade. In other words it seems natural to regard the existing Cephalochorda as the relics of a great group which flourished in remote geological ages, and which, owing to competition with higher forms, or to environmental changes, or to some other reason, is represented to-day by a few species only. The interesting question then arises to what extent a group, such as the Cephalochorda, which has persisted from remote antiquity, has acquired a fixity of type, and to what extent it may be supposed to have attained to a position of organic stability in which it is incapable of giving origin to new species under altered conditions. If we admit the existence of Natural Selection as a factor in evolution the problem resolves itself into the question whether the variations exhibited are of sufficient magnitude and frequency to allow of the conception of this factor coming into operation.

To consider only the feature of meristic variation, most of the Vertebrata, and especially the lower forms, exhibit considerable variation in the number of segments of which the body is composed. In certain other vertebrates again the number of segments is nearly constant. Especially is this the case among forms which have reached a high pitch of specialization, such as the mackerel[1] among fishes, the Anurous Amphibia, and many birds and mammals. Accompanying this high degree of specialization there would seem to be a loss of plasticity in the meristic series of which the animal is composed. To what extent is this fixity of form to be found among groups of great antiquity as well as among those of high specialization?

Amphioxus would seem to afford an admirable object for consideration in this connection, and with regard to the amount of variation it shews there is some difference of opinion. In his recent work on Nautilus Willey[2] has referred to Amphioxus as "another example of a relatively fixed type which presents little range of variation." On the other hand Kirkaldy[3] has shown that the number of myotomes in all the species known is subject to considerable variation. In this connection it must be mentioned, that although the *range* of variation may be of not inconsiderable extent, the species may yet be a comparatively non-variable one. The number of specimens which group themselves closely round the mean may be very large, whilst those which lie on either side of the mean may be numerically very few. In

[1] Williamson, H. C., *Eighteenth Report of Scottish Fishery Board*, 1899.

[2] Willey, A., *Zoological Results*, Pt. VI. 1902 (p. 811).

[3] Kirkaldy, J. W., *Quart. Journ. Mic. Sci.*, 1895.

TABLE I.

Asymmetron lucayanum (28 specimens).

	Total number of myotomes	Number of myotomes from			Length in mm.
		Head to atriopore	Atriopore to anus	Anus to tip of tail	
	64	43	9	12	20
	65	44	9	12	23
	66	44	9	13	18
	66	44	9	13	20
	66	44	9	13	21
	66	44	9	13	21
	66	44	9	13	22
	66	44	9	13	24
	66	44	9	13	24
	66	44	9	13	25
	66	44	9	13	27
	66	44	9	13	27
	66	44	9	13	30
	66	44	10	12	15
	66	44	10	12	23
	66	44	10	12	25
	66	45	10	11	23
	67	44	10	13	18
	67	44	10	13	23
	67	44	10	13	24
	67	45	9	13	22
	67	46	9	13	28
	68	44	11	13	25
	68	45	10	13	30
	68	45	10	13	25
	69	46	13	10	27
	70	46	12	12	31
	71	45	13	13	21
Mean ...	*66·71*	*44·36*	*9·79*	*12·61*	*23·6*
Mode ...	*66*	*44*	*9*	*13*	—
Range...	*8*	*4*	*5*	*4*	15—30
σ	*±1·435*	—	—	—	—
P.E.σ ...	*± ·129*	—	—	—	—

TABLE II. *Heteropleuron maldivense* (45 specimens).

	Total number of myotomes	Head to atriopore	Atriopore to anus	Anus to tip of tail	Number of gonads	Position of gonads	Length in mm.
	70	42	16	12	24	10—34	21·0
	71	44	16	11	30	9—39	23·0
	71	43	16	12	28	9—37	20·0
	71	43	16	12	27	12—39	18·0
	71	43	14	14	27	10—37	26·5
	72	45	15	12	27	10—37	19·5
	72	45	15	12	26	13—39	20·0
	72	44	17	11	26	10—36	26·0
	72	44	16	12	28	10—38	21·0
	72	44	16	12	25	10—35	18·0
	72	43	17	12	broken	away	18·0
	73	46	15	12	28	11—39	21·5
	73	46	15	12	26	10—36	26·0
	73	46	15	12	broken	away	23·5
	73	45	16	12	28	9—37	20·5
	73	45	16	12	28	11—39	20·5
	73	45	16	12	28	11—39	28·0
	73	45	16	12	28	9—37	20·5
	73	45	16	12	28	?	28·5
	73	45	16	12	27	9—36	18·5
	73	45	16	12	27	10—37	18·0
	73	45	16	12	27	10—37	21·0
	73	45	16	12	27	11—38	20·0
	73	45	16	12	27	10—37	22·0
	73	45	16	12	26	11—37	20·0
	73	45	16	12	26	10—36	21·0
	73	45	16	12	25	11—35	27·0
	73	45	16	12	25	11—36	18·5
	73	45	16	12	25	11—36	20·0
	73	45	16	12	25	9—34	27·0
	73	45	16	12	25	10—35	23·0
	73	45	16	12	25	?	20·0
	73	45	16	12	24	10—34	30·0
	73	45	16	12	24	11—35	22·0
	73	45	16	12	24	11—35	21·0
	73	45	16	12	23	12—35	20·0
	73	44	17	12	23	12—35	20·0
	73	44	16	13	26	11—36	23·0
	73	44	16	13	25	10—35	30·0
	73	44	16	13	23	10—33	22·0
	73	42	17	14	25	?	19·0
	74	46	16	12	26	?	20·0
	74	46	15	13	broken	away	26·0
	74	45	16	13	25	11—36	21·5
	76	45	17	14	25	?	24·0
Mean ...	*72·75*	*44·62*	*15·93*	*12·2*	*26·0*	—	*22·1*
Mode ...	*73*	*45*	*16*	*12*	*25*	—	—
Range...	*7*	*5*	*4*	*4*	*8*	—	—
σ	*±·879*	—	—	—	*±1·618*	—	—
P.E.σ ...	*±·062*	—	—	—	*± ·119*	—	—

such a case the variability of the species as measured by the ordinary methods will be low even though the range of variation is considerable. With the view to throwing some light on the character of such variation among the Branchiostomidae certain measurements were made on 28 specimens of *Asymmetron lucayanum* and 45 specimens of *Heteropleuron maldivense*. The results are given in Tables I. and II. It is to be regretted that a larger amount of material was not examined by Mr C. Forster Cooper, to whom I am indebted for the measurements recorded for *A. lucayanum* and *H. maldivense*.

A glance at the two tables is sufficient to shew that the amount of meristic variation in these two species of Cephalochorda is considerable. And not only the range of variations but also their amount as measured by the standard deviation would appear to be large. Observations on the meristic variability of the various groups of Vertebrata are unfortunately at present very scarce, but such as are available for comparison with the Branchiostomidae are given in the appended table.

TABLE III.[1]

	Locality	σ	P.E.σ	C.V.	Number of specimens
Asymmetron lucayanum.....	Maldive Is.	1·435	±·129	2·15	28
Heteropleuron maldivense	Zanzibar	·879	±·062	1·21	45
Spinax niger (♀ adults).....	Bergen	1·016	±·040	1·55	144
" " (♂ ").....	"	1·040	±·054	1·59	84
" " (♂ & ♀ embryos)...	"	1·045	±·038	1·61	168
Scyllium canicula.....	Plymouth	1·522	±·092	1·82	53
Pleuronectes platessa	Heligoland	·56	±·014	1·30	341
" "	Helder	·675	±·023	1·57	200
" "	Lowestoft	·54	±·019	1·25	170
" "	Grimsby	·59	±·025	1·37	120
" "	Aberdeen	·54	±·016	1·25	254
" "	Solway Firth	·62	±·021	1·44	197
" "	Baltic	1·02	±·071	2·40	47
Clypea harengus	Dollarts	·773	±·044	1·12	69
" "	Fair Is.	·667	±·040	1·18	61
" "	Utsire	1·007	±·066	1·75	52
" "	Stockholm	·745	±·049	1·34	53
" "	Zuidersee	·823	±·053	1·49	54
Necturus maculatus.....	N. America	1·942	±·092	4·15	100

[1] The following customary abbreviations have been made use of:—

σ = Standard deviation = $\sqrt{\frac{\Sigma(x^2 \cdot f)}{n}}$,

P.E.σ = Probable error of standard deviation = $\pm \cdot 6745 \frac{\sigma}{\sqrt{2n}}$,

C.V. = Coefficient of variability = $\frac{\sigma \times 100}{M}$,

where M = the Mean of the number of segments and n = total number of specimens.

For a simple explanation of these formulae *vide* Pearson, *The Grammar of Science*, 1900, p. 384 *et seq.*

The figures given in this table have been calculated from data given in the following papers:—

Pleuronectes. H. M. KYLE, *Eighteenth Annual Report of the Scottish Fishery Board*, 1899.

Clypea. F. HEINCKE, *Naturgeschichte des Herings*, 1898.

Necturus. H. BUMPUS, *Journ. Morph.* vol. XII. 1897.

Spinax and *Scyllium* from unpublished data collected by the writer.

Considering first the case of *Asymmetron*, it will be seen that the variability as measured by the standard deviation (σ) is greater than that found in the Teleosteans and in *Spinax*, being only excelled by that found in *Scyllium* and in *Necturus*. This however is not an altogether satisfactory criterion since it does not take into account the fact that we are dealing with series of segments in which the total number differs greatly in the different groups. The mean number of segments is 66·7 in *Asymmetron*, whilst in *Spinax*[1] it is about 65 and in *Necturus* only 47. This difficulty can to some extent be eliminated by considering the coefficient of variation (C.V.) instead of the standard deviation. When this is done it is found that the value for *Asymmetron* comes out higher than that for all the Elasmobranchs, being only exceeded by the value for *Necturus* and for a local race of Baltic plaice. On the other hand the value for *Heteropleuron* comes out somewhat lower than that for the Elasmobranchs and for most of the plaice and herrings, and very much lower than the value for *Necturus*. When however it is borne in mind that the Vertebrates here dealt with are probably among the most variable species of the group it seems only fair to conclude that the Branchiostomidae form a highly variable group in respect of their meristic segmentation, and that we must give up the idea of their being characterized by fixity of form, at any rate with regard to this feature.

Why then, it may be asked, are the species of Cephalochorda so few in number? The great number of offspring would lead us to suppose that the Struggle for Existence must be severe; the meristic variability of the species hitherto investigated is considerable; and lastly we have no reason for doubting that the Principle of Heredity also holds good in this connection. Moreover many of the species occur in great abundance. We cannot but ask ourselves how it is that, under what seem at first sight such favourable circumstances for its operation, the factor of Natural Selection has not come into play and produced in the group a far greater diversity of form than we meet with. Is it possible that Natural Selection now plays a comparatively unimportant *rôle* in the history of the group as regards the character of meristic segmentation?

In this connection it must not be forgotten that the life of the Branchiostomidae is completed under two entirely different environments. We find at first a pelagic larva produced in enormous numbers, but in which the total number of myotomes is not reached until towards the conclusion of this stage of its existence. It is therefore not easy to see how the high death-rate at this period can affect the ultimate number of segments, *i.e.* whether in this respect it is truly selective. Later we have to deal with an adult so adapted through long ages to living in sand that the constancy and uniformity of its surroundings would seem to reduce the struggle with the environment to a minimum. Again, the greatest variability would hardly be looked for in a species which had been exposed for

[1] In reckoning the number of segments in *Spinax* and in *Scyllium* each pair of "half vertebrae" which characterize the Elasmobranch tail region have been counted as a single segment.

immense periods of time to a selective death-rate in a uniform environment. These considerations coupled with the small number of existing species give us some reason for doubting whether Natural Selection plays much part in determining the number of segments of which these animals are composed.

Supposing then that Natural Selection is not at work on the meristic characters of the Cephalochorda, there may yet be some other factor active in producing modifications. Sexual selection is clearly out of the question and external fertilization seems to preclude the possibility of physiological selection. There yet remains to be considered the factor suggested by Karl Pearson to which he has applied the term Genetic (or Reproductive) Selection. Pearson has suggested that certain characters may be associated with increased fertility. Such characters would tend to assert themselves under a high death-rate, which at the same time need not be selective. To quote his own words—"Those who deny natural selection must, if we can show the existence of genetic selection, still admit that evolution is a reality, for genetic selection produces a continuous change of type which can only be held in check by more or less stringent selection[1]." We have then to enquire whether fertility is really correlated with any other characters,—in this case with the number of somites. And in this connection the Cephalochorda are most favourable objects for study not only from their mode of breeding, but also from the fact that the number of gonads affords us a quick and easy method of estimating the relative fertility in different individuals[2]. Their numerical range of variation is exceedingly large (cf. Table II.) and their variability as measured by the coefficient of variation (C.V. = 6·4) is extremely high compared with that for the total number of segments. That such gonidial variations are to some extent associated with meristic changes in the total number of somites may be seen in the following table for *Heteropleuron maldivense.*

TABLE IV.

Total no. of somites	No. of specimens	Average no. of gonads
70—72	10	26·8
73	29	25·8
74—76	3	25·3

This shews that increase in the number of gonads is associated with a decrease in the number of segments and that the differences are well marked. It may be further shewn that there exists no correlation between the number of gonads and the total length of the specimens (Table V.), or again between the total length and the number of somites in the different specimens.

Hence the correlation shewn in Table IV. is probably direct and not due to gonidial and myotomic variations being both dependent upon some other quality such as length. Unfortunately the data here available are not more than sufficient to warrant these results being regarded as more than a plausible suggestion. Before it would be possible to prove that genetic, and not natural selection, is the factor at work on the meristic segmentation of the

[1] *The Grammar of Science*, 2nd edition, 1900, p. 439.

[2] It is assumed here that the average size of the separate gonads is approximately the same in individuals with a longer and with a shorter series of them. There seems at present no reason against assuming this but direct observations would of course be necessary.

Cephalochorda it would be necessary to establish the correlation between the number of gonads and the total number of somites on a large number of specimens. It would be further necessary to examine the number of somites in a large number at different stages of late larval and early adult life with a view to discovering whether a selective death-rate existed. At the same time it would be interesting to examine the correlation between the number of gonads and the number of somites in the different regions of the animal's body, questions which paucity of data forbids any attempt at answering here.

TABLE V.

	Number of gonads							
	23	24	25	26	27	28	29	30
Average total length (mm.)...	20·7	23·5	22·5	22·3	20·4	22·5	—	23
Number of specimens	3	4	11	7	8	8	—	1

To sum up briefly what has been written above it may be said (1) that the Cephalochorda are with regard to their meristic features a very variable group; (2) that there is reason for doubting that natural selection is now playing much part in modifying them; (3) that genetic selection is probably a factor of considerable importance in modifying the meristic features of the group; and (4) that the conclusions arrived at here are purely tentative but suggest that an ampler study of the group in this connection might be expected to be of considerable interest.

AVES.

By H. Gadow, M.A., Ph.D., F.R.S., and J. Stanley Gardiner, M.A.

INTRODUCTION.

As was to be expected of such small, although numerous, somewhat outlying islands, naturally without much physical variety, the avifauna is composed of few species only, and most of these either marine or waders. None of the birds are peculiar to the islands. The 26 species fall into several categories:—

I. **Permanent residents,** which also breed: *Puffinus, Phaethon, Fregata, Butorides, Ardea, Nettium, Gallinula, Dromas, Anous, Sterna, Corvus,* and possibly *Asio.* The Indian Crow is the only typical land bird of this category. Most of these species have a very wide distribution in the temperate or tropical parts of the Old World.

II. **Winter visitors,** with their natural home on the Asiatic Continent: *Charadrius, Totanus, Falco, Circus, Numenius, Eudynamis, Asio,* and *Hirundo urbica.* Specimens of the full snipe were seen to remain on certain of the islands throughout the year, but it would be very abnormal, if it did really breed on any of them.

III. **Accidental visitors** from the nearest land, e.g. India and Ceylon: *Hirundo rustica, Herodias garzetta,* and the Ceylonese Parakeet, *Palaeornis calthropae.* The latter is a rather unexpected visitor, hitherto not recorded so far from its home.

Remarkable, and not easily accounted for, is the total absence of Finches, Starlings, and above all, of Pigeons.

The notes on the different species have been for the most part copied from the original diary. Unless the species is mentioned in "The Fauna of British Indian Birds," by W. T. Blanford and Eugene W. Oates, a reference is given to the British Museum Catalogue. The species marked with a star have been observed only, but we do not think that there can be in any case any doubt as to the species, which were generally described, when seen, in Mr Stanley Gardiner's diary.

A remarkable feature at Hulule was the daily retirement of all birds from about 11 a.m. to 3 p.m. The heron and tropic-bird were then at rest in the coconut trees, and even the ubiquitous crows retired into the low bushes near the village. The terns about noon might commonly be seen to have settled on the north point of the island, while the waders had long before retreated to the shores of some one of the uninhabited islands.

SYSTEMATIC LIST.

1. *Puffinus persicus.* Fauna, Brit. Ind., IV, p. 356.

In every one of the three adult specimens brought home the primary quill is slightly (about 0·1 inch) longer than the second. The longest of the under-tail coverts are sooty. In one specimen the shorter under-tail coverts are paler, with whitish outer webs; white towards the base of both webs. In the two other specimens these coverts are dark, sooty, just visibly tipped with white.

"This bird was found breeding in great numbers in Difuri and Olivelifuri to the east of Fadifolu Atoll. The single white egg was placed at the slightly hollowed-out end of a hole, about a yard deep, either in the sand or under a coconut or other tree. The burrows appeared to be those of a large crab (*Cardiosoma carnifex*), that had been by some means dispossessed. On Dec. 29, 1899, we opened several of the holes, in some finding crabs and in others eggs or young birds. The latter are regularly taken and eaten by the natives of the atoll."

2. *Phaëthon lepturus.* Ogilvie-Grant, Cat. B. M., XXVI, p. 453 (1898). Adult, nestling and egg.

The above specimens of this Tropic-bird were taken at Hebaridu, South Mahlosmadulu Atoll, on Nov. 24, 1899. "In a hollowed-out branch of a Tulip-tree (*Hernandea peltata*) I caught three of these birds sitting. The branch sloped upwards slightly, and the nests were situated above, but within sight of one another. The nests were made of the decaying wood with sticks, pieces of grass and coconut leaves. The top bird was a female with one nestling, the middle bird a male with an empty nest and the lower bird a female with 1 egg. The male sat just as tightly as the females and indeed fought harder than they did when I removed him. The females I allowed to go free, when they at once proceeded to a Pandanus tree, up which they climbed, so as to get a jump off for flight. My boys, curiously enough, brought down from a neighbouring tree 2 females and 1 male, both the former with young."

The species was seen in nearly every atoll in the group, even in Addu. At Hulule, Male Atoll, it circled overhead daily, filling the air with its shrill shrieks.

*3. *Fregata ariel.* Fauna Brit. Ind., IV, p. 338. The Smaller Frigate-bird.

Solitary birds of this species were frequently seen in the Maldives. Its only breeding-place seemed to be at Olugeri at the extreme south of Mahlosmadulu. This is an uninhabited island covered with large timber trees (*Calophyllum inophyllum* and *Terminalia catappa*), in the tops of which the nests are placed. The appearance is not unlike an immense rookery, allowing for the difference in the more massive mode of growth of the above trees as compared with English timber. On Nov. 13, 1899, during our stay at Turadu, a neighbouring island, the people and our crew made a night expedition to the rookery, and brought back about 40 young birds nearly fledged. No eggs were found.

4. *Butorides javanica.* Fauna Brit. Ind., IV, p. 395.

The Little Green Heron is found in every island of the Maldives, where there is dense jungle, being observed in the Mahlos, Miladumadulu, Male, Nilandu, Suvadiva and Addu Atolls.

It especially frequents the mangroves at the edges of swamps, and breeds in the same places. It is never seen on the shores nor in the open, unless flushed.

5. *Ardea cinerea.* Fauna Brit. Ind., IV, p. 382.

The Common Grey Heron is found in Minikoi and in all parts of the Maldive Group. Solitary birds frequent the shore, the boulder zone and those parts of the reef which are exposed at low tide. The species feeds largely on the beach crabs (*Ocypode*), with the shells of which it strews the shores. The bird is especially numerous in the west of North Mahlosmadulu, roosting in the south island of Bodu-faro and in Limbo-Kandu. The nest is placed in the crown of a tall coconut tree. One bird reared its young during my visit to Minikoi on Wiringili island (July and August, 1899).

*6. *Herodias garzetta.* Fauna Brit. Ind., IV, p. 387. The Little Egret.

A single bird appeared in the clearing round the lighthouse at Minikoi in July, 1899, and I saw a second in Hedufuri, S. Mahlosmadulu. There were also two tamed birds in Huludu, Addu Atoll. The presence of one of these birds in any island—their colour, white, being beloved of Mahommed—is considered a lucky sign. Neither my companion nor I hence cared to shoot a specimen.

*7. *Nettium crecca.* Fauna Brit. Ind., IV, p. 443. The Common Teal.

A pair of these birds were seen in a small pool at Maduwari, S. Mahlosmadulu. Several were also observed in Miladumadulu, seeming to frequent a series of large fresh-water lakes in the islands of the east rim between Furnadu and Landu. In Kendikolu, one of these islands, Mr Forster Cooper found two old birds and three young ones.

8. *Falco tinnunculus.* Fauna Brit. Ind., III, p. 428.

The two female specimens of Kestrel brought home are rather long winged.

Wing,	9·8	inches	and	10·5	inches.	Blandford	gives	9·5 inches.
Tail,	6·5	„	„	7·3	„	„	„	6·75 „
Tarsus,	1·5	„	„	1·6	„	„	„	1·5 „

9. *Circus macrurus.* Fauna Brit. Ind., III, p. 381. The Pale Harrier.

10. *Circus cineraceus.* Fauna Brit. Ind., III, p. 383. Montagu's Harrier.

The Kestrel and these two Harriers were all very common from October to February in the northern part of the Maldives. None, however, were seen in Addu, Suvadiva or elsewhere in April. Although only a few specimens of the Harriers were preserved, a very large number were shot by request of the natives, whose chickens are often killed and carried off by them.

11. *Gallinula* (*Amaurornis*) *phoenicura.* Fauna Brit. Ind., IV, p. 173. Native Maldivian name "kambili." The White-breasted Water-hen.

This Rail is found sparingly right through the whole Maldive Archipelago, being observed even in Midu and Maradu Islands in Addu Atoll. A few inhabit the jungle of the south end of Minikoi, and at the end of July, 1899, a young bird was taken from the nest, a mere hollow in the ground among some dry rushes. In Kendikolu, Miladumadulu Atoll, the species is very numerous in the mangrove swamps around some fresh-water pools, and in

Hulule two or three birds used daily to visit our midden. In some islands the natives regularly catch them by means of nooses, laid down in their runs.

*12. *Charadrius fulvus.* Fauna Brit. Ind., IV, p. 234.

The Eastern Golden Plover is often tamed both in the Maldives and Laccadives. There were two in Minikoi and several in Male and the various islands of Addu Atoll. In addition a small flock was seen wild in Bodu Mandu, Miladumadulu Atoll.

13. *Numenius phaeopus.* Fauna Brit. Ind., IV, p. 253.

The Whimbrel is a regular visitor to the Maldives from November to March, when it proceeds northwards again. Three or four birds are occasionally seen together on the wing, but single specimens are more often found and are then exceedingly shy of approach. The species was frequently noticed in Mahlosmadulu and Miladumadulu, and a single bird frequented the reefs of Hulule, Male Atoll.

14. *Gallinago coelestis.* Fauna Brit. Ind., IV, p. 286.

The Full Snipe was extremely numerous in April, 1900, on the mud-flats of Addu Atoll at low tide. At high tide it frequented in particular a large rush-covered swamp extending along the middle of the north-eastern island between the villages of Huludu and Midu. The bird is said to be plentiful in this Atoll at all seasons of the year. It therefore must breed there, and indeed its nest—on tussocks of the rush—and eggs appeared on enquiry to be well-known to the natives. The species may have been seen, but it was never identified nor shot in any other part of the Maldives.

15. *Totanus hypoleucus.* Fauna Brit. Ind., IV, p. 260.

The Common Sandpiper was observed at Minikoi in August and frequently in the Maldives between October and April. It generally occurs in single pairs or small flocks—seldom more than six in number frequenting the rocky shores of the islands.

16. *Dromas ardeola.* Fauna Brit. Ind., IV, p. 208.

The Crab-Plover was observed only in the middle of December, 1899, in Miladumadulu Atoll. It was especially numerous round Furnadu, affecting a series of sand-banks along the reefs. Several small flocks of four to about a dozen were seen, flying from place to place and feeding, where the waves lap against the beaches, on small Ocypodes and other Crustacea. The Maldivians say that the species does not breed in their Group, and indeed—assuming that the accounts of its nesting are correct—as the sand is all very loose, it is difficult to see where it could do so.

The species ranges from Madagascar and East Africa to Ceylon, the Andamans and Nicobars; it has also been recorded on the Laccadives.

17. *Anous tenuirostris = leucocapillus* Gould. Fauna Brit. Ind., IV, p. 326.

The White-headed Noddy is nowhere common, but found throughout the whole of the Maldives. It breeds in S. Mahlosmadulu and other atolls on the Screw Pine trees (Pandanus).

One of the adult specimens, obtained on April 14, 1900, was moulting. An adult female and nestling were taken from a Pandanus tree on Mabaru, S. Mahlosmadulu by Mr Forster Cooper on Nov. 26, 1899.

18. *Sterna fuliginosa.* Fauna Brit. Ind., IV, p. 324. The Sooty Tern.

One immature specimen from Minikoi; most of the feathers above have whitish or pale brownish tips. Recorded by Hume from the Laccadives.

19. *Sterna melanauchen.* Fauna Brit. Ind., IV, p. 322. The Black-naped Tern.

The two adult specimens have the following measurements, which do not seem to agree exactly with previous records: culmen 1·4 and 1·6 inches; wing 7·9 and 8·5 inches; tarsus 0·6 and 0·65 inch.

The Terns preceding and following this species are both abundant in the Maldives, but this is by far the commonest, sometimes large flocks almost completely covering the sand-banks which are exposed at low tide. All three species were seen from October to January, but not subsequent to the latter month, seeming almost to leave with the full setting-in of the north-east monsoon.

20. *Sterna bernsteini.* Saunders, Cat. B. M., XXXV, p. 96 (1896).

21. *Eudynamis honorata.* Fauna Brit. Ind., III, p. 229. *The Indian Koel.* Maldivan "kooveli."

This Cuckoo—the male called by the natives *kalu* (black) *kooveli* and the female *hudu* (light) *kooveli*—was constantly seen in the months of November and December in Mahlosmadulu, Miladumadulu and Fadifolu. A pair frequented the Banyan trees in Hulule, Male Atoll, in January but disappeared at the beginning of February. The bird was not seen in April in Addu or Suvadiva Atolls.

The species in the Maldives keeps to the densest part of the jungle, frequenting the Breadfruit, Banyan and *Calophyllum* trees. Males were much less numerous than females, three or four of the latter being seen to one of the former. The natives of Mahlosmadulu, even in the Maldives noteably unobservant, know the difference between the males and females, and state that a few breed every year in their islands.

Concerning outlying islands this cuckoo has been found also on the South Andamans, on Little Coco Island, and by H. O. Forbes on the Laccadives in the month of February.

*22. *Palaeornis calthropae.* Fauna Brit. Ind., III, p. 256. Layard's Ceylon Parakeet.

A pair of green parakeets a little bigger than a thrush and of a brilliant green colour all over—were on two occasions at the end of January seen at Hulule, Male Atoll. The birds were among the *funa* trees (*Calophyllum inophyllum*), the nuts of which they seemed to be eating. They were probably driven down by the heavy north-easterly winds, at that time experienced in the Maldives.

23. *Asio accipitrinus.* Fauna Brit. Ind., III, p. 271.

A dead specimen of the Short-eared Owl was found in Furudu, Goifurfehendu Atoll, in October and one was shot in Kendikolu, Miladumadulu Atoll, in December. In January and February two or three were to be seen nightly flying over the low bushy land to the north and east of Hulule, Male Atoll. In April the bird was also seen in Suvadiva and Addu Atolls, and at Male Island.

*24. *Hirundo rustica.* Fauna Brit. Ind., II, p. 277.

Several swallows appeared at Minikoi on Sept. 1, but were not seen subsequent to Sept. 4.

*25. *Hirundo urbica.* Fauna Brit. Ind., II, p. 269.

At the end of January a number of Martins arrived at Hulule, and were to be seen daily from about 4 to 6 p.m., circling over the village. During the whole of February also they were observed over the neighbouring island of Male.

26. *Corvus splendens.* Fauna Brit. Ind., I, p. 20. Maldivan "kalu."

The Indian Crow is found in every inhabited island of the Maldives, but is curiously enough absent from Minikoi. The birds are regular inhabitants and scavengers of the villages, glutting themselves in the fishing season with the guts of the bonito. The natives state that they are permanent residents and breed in the islands. Their breeding season must then be between May and September, *i.e.* in the south-west monsoon, as we never saw any trace of nesting in the other months.

THE EARTHWORMS OF THE MALDIVE AND LACCADIVE ISLANDS.

By Frank E. Beddard, F.R.S., *Vice-Secretary of the Zoological Society of London.*

I believe that no collection of earthworms from these islands has ever been reported upon. I am therefore particularly obliged to Mr J. Stanley Gardiner and his colleagues for the considerable collection of these Annelids which they have made with so much care and have been so good as to place in my hands for study and description.

I have no general conclusions of importance to urge as a result of my examination of this collection, save to emphasise the belief, now becoming firmly founded, that these Annelids on account of the practical impossibility of their unassisted migration over tracts of sea will serve as the very best test of whether a given isolated island is truly oceanic or not. This is however subject, as Dr Michaelsen has pointed out, to one exception and that is the genus *Pontodrilus*. This genus, of which several species are now known, as a rule but not always lives upon the sea-shore in decaying sea-weed and such like *débris*; the nature of its habitat therefore precludes any impossibility of chance migration from the shores of one tract of land to the shores of another.

The present collection contains one undoubtedly new species of this nearly ubiquitous genus. And that is the only new form which I have found among the three species of earthworms upon which I report here. The rest are precisely what might be expected from the proximity of the islands to Ceylon and India; the two species are both of them common Oriental species. It is very probably in part the abundance of *Megascolex mauritii* which has led to its so wide range. But the relations between the ease with which various species can be transported to regions of quite a different climate and flourish there and other conditions have not yet been guessed at. The material in the way of fact is at present hardly sufficiently large.

1. *Pontodrilus laccadivensis* n. sp.

I have examined a large number of examples of this species which I at first took to be Dr Michaelsen's *P. matshusimensis, var. chathamianus*[1] on account of the nearly similar disposition of the anterior genital papillae. There is, however, not an exact correspondence in the position and number of them, while other features in the organisation of this *Pontodrilus* from the Laccadives forbid its identification with Michaelsen's variety. There is no other species to which it presents so close a likeness in external characters.

It is a long, slender species like other *Pontodrilus*, of 90 to 110 mm. in length. The prostomium impinges slightly upon the buccal ring. The clitellum occupies segments XIII—XVII, and there is always a ventral band left devoid of modification. I have studied 13 fully mature examples of this species, all of which show some of the anticlitellian papillae which distinguish this species from all other *Pontodrilus* except Michaelsen's variety. These papillae

[1] *Zool. Jahrb. Syst. Abth.* XII. p. 220.

are not, however, equally or similarly developed in all. In seven examples there are two papillae plainly visible; one lies between segments XII/XIII and is, as a rule, much more conspicuous by reason of its convexity than the second papilla, which is *not* intersegmental in its position. It lies on XIV, though near to the anterior margin of that segment and not between XIII/XIV. In six individuals one or other of these papillae was missing. In the last individual the two papillae were between XI/XII and XII/XIII, and both were of the same character. I may observe that the papilla upon segment XIV and that upon segments XII/XIII occasionally showed considerable traces of being double. In no individual did I find a papilla between XIV/XV such as is mentioned by Michaelsen in his description of *P. matsushimensis var. chathamianus.* In addition to these papillae there are, as Michaelsen has pointed out, others situated more anteriorly still.

In four individuals there were very evident long, dumb-bell shaped thickenings of the integument occupying the intersegmentary regions VII/VIII and VIII/IX. Each is median and unpaired and ends at the conspicuous orifices of the spermathecae. They do not obliterate the intersegmental grooves. The orifices of the spermathecae correspond to the outer section of the ventral couple. The male pores lie in an area which appears to me to be exactly like that figured by Izuka for *Pontodrilus matsushimensis*[1]. It is quite conspicuous even in immature individuals. So also is the one genital papilla which follows the male pores. This is as usual on the intersegment XIX/XX and is generally hollowed out and sucker-like. It is even apt to be squarish in outline.

As to the internal characters of this species the chief facts which I have observed are the following: the specially thickened mesenteries are those which divide segments VI/XIII, and they are all cup-shaped, with the concavity, of course, anterior. The gizzard is feeble, but still recognisable; it lies in the VIIth segment. In the XIIIth segment are a pair of conspicuous and presumably contractile hearts. The nephridia begin in segment XIII.

The racemose sperm sacs lie in segments XI and XII. The spermathecae are plainly divisible into a thin walled sac and a shorter thick walled duct. The tubular diverticulum is fully as long as the pouch. The spermiducal glands have a long, curved, muscular duct of glittering appearance, fully 2 mm. long.

Locality: Minikoi, Laccadive Islands; and Goidu, Goifurfehendu[2] and Hedufuri, S. Mahlos[3], both Maldive Islands.

2. *Megascolex mauritii* (Kimb.).

Lampito mauritii Kinberg Öfv. Sv. Ak. Förh. 1867, p. 103.

This very common and widely spread Oriental species is abundant in the collection.

Localities: Kumfinadu and Madu, both S. Mahlos; Maungudu, Miladumadulu; Goidu, Goifurfehendu; Hulule, Male; Maradu, Addu, all Maldive Islands; and Minikoi, Laccadive Islands.

3. *Perionyx*, sp.

A number of examples of this characteristic Oriental genus were collected, but they were quite immature and I am therefore unable to identify the species.

Localities: Madu, S. Mahlos; Fainu, N. Mahlos; and Maradu, Addu, all Maldive Islands.

[1] *Annot. Zool. Japon.* II. i. p. 21, Tab. 2, fig. 1.

[2] A single specimen from this locality may possibly not belong to the same species; it was immature, but I refer it to *P. laccadivensis* on account of the exact similarity of the spermiducal glands and of its general appearance to that species.

[3] The same observation applies to a few specimens from this locality. The spermathecae however were well developed and had each a long diverticulum, thus increasing the likeness to the examples from the Laccadives.

THE MALDIVE AND LACCADIVE GROUPS, WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN (*concluded*).

By J. Stanley Gardiner, M.A., *Fellow of Gonville and Caius College, and late Balfour Student in the University of Cambridge.*

(With Plates XIX—XXI. and Text-Figs. 90—109.)

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APPENDIX. B.

In the following account the condition of each bank is summarised at the beginning of its section. A detailed account of the parts visited follows in smaller type.

I. Goifurfehendu[1] (Fig. 90).

This atoll is one of the most perfect in the group, having only a single passage with 4—6 fathoms of water to the south. Its situation, on the west side of the wide channel that separates the long double line of banks into two parts (Pl. IX.), causes it to be more exposed and subject to more purely oceanic conditions than any other of the more perfect atolls of small size except Addu. It is yet to some extent protected by the east horn of S. Mahlosmadulu, which seemed to me to divert the currents of the N.E. monsoon more or less away from its northern reef. The S.W. monsoon naturally impinges mainly on its south and west sides, leaving the N.E. part little affected. Perhaps it is owing to these causes that the greater part of the land lies on the northern rim of the atoll.

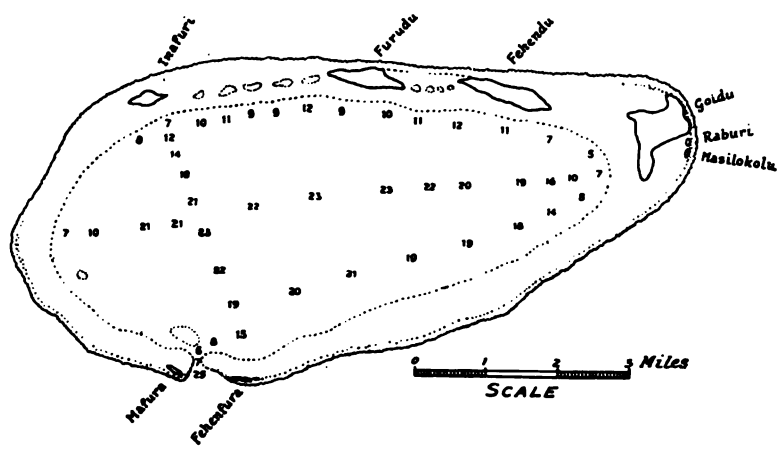


Fig. 90. Goifurfehendu Atoll.

There is little to show the past history of Goifurfehendu, but a line of coral rock and two islets to the west of Goidu, together with a series of masses on either side of the passage, prove elevation (Figs. 92—3). A certain number of coral pinnacles, running from Goidu westwards in the boulder zone of the reef as far as the passage, indicates that the elevated land once probably extended along the whole south side of the atoll.

The comparatively recent connection of Fehendu and Furudu is certain, and there are again sand banks forming along the whole northern reef. There is no indication that the northern islands owe their origin to elevation in any way. Indeed, it is more than probable that their formation was in the first place due to the piling up of sand by the waves and wind from off the sand flats that fringe the lagoon.

The lagoon is increasing in size at the expense of its encircling reef. It is singularly open, no trace of coral growth, except near the encircling reefs, nor of shoaling being anywhere found. Its bottom is everywhere covered by a muddy, calcareous sand, coarser near the reefs

[1] Mr Forster Cooper and I spent 10 days in this atoll at the beginning of November, 1899. In addition to visiting all the islands and examining the reefs in every situation, we put down a number of dredgings in the lagoon, which however only served to show the great poverty of both free and fixed animal life, save in the immediate proximity of the encircling reefs or of shoals.

and finer towards the centre of the lagoon, formed mainly of coral fragments, but containing also *Halimeda* remains, bottom-living Foraminifera and a few shells of pelagic animals.

Goidu island lies with its eastern side right on the reef-flat, which off it approximates to that of the east side of Minikoi near Mou-Rambu Point (p. 40), being about 50 yards in breadth from the base of the beach with two ill-defined terraces and studded all over with pinnacles and masses of the elevated coral rock. The beach behind is mainly formed of the solid rock, slightly overlaid with loose stones. It is the outer edge of a rocky belt of land, about 70 yards broad by 4—5 feet above the high tide level, which behind merges into the sand forming the rest of the island. The latter area averages 2½ feet above the high tide limit, but a small mangrove swamp exists behind the northern half of the rocky belt. To the north the latter continues out into a point on the boulder zone, and to the south masses of rock on and inside the same zone show that it was once joined up to two rocky islets, **Raburi** and **Masilokolu**. The rocky land, wherever exposed, shows some slight loss, but the latter is more marked in two bays that have formed to the south and north of Goidu, in which there is some fallen timber. These are separated from the lagoon by two very prominent points of the land, on which the sand from the two bays appears to be piled up so that they are, if anything, growing out along the encircling reef of the atoll. The west or lagoon side of the island has a broad sandy beach with no rock, and exhibits no marked change of any sort.

Fehendu extends almost east and west for about 1½ miles. It is formed entirely of sand, and lies to the west about 100 yards and to the east about 400 yards behind the boulder zone. To the north or seaward side the whole shore is studded with lines of beach sandstone which

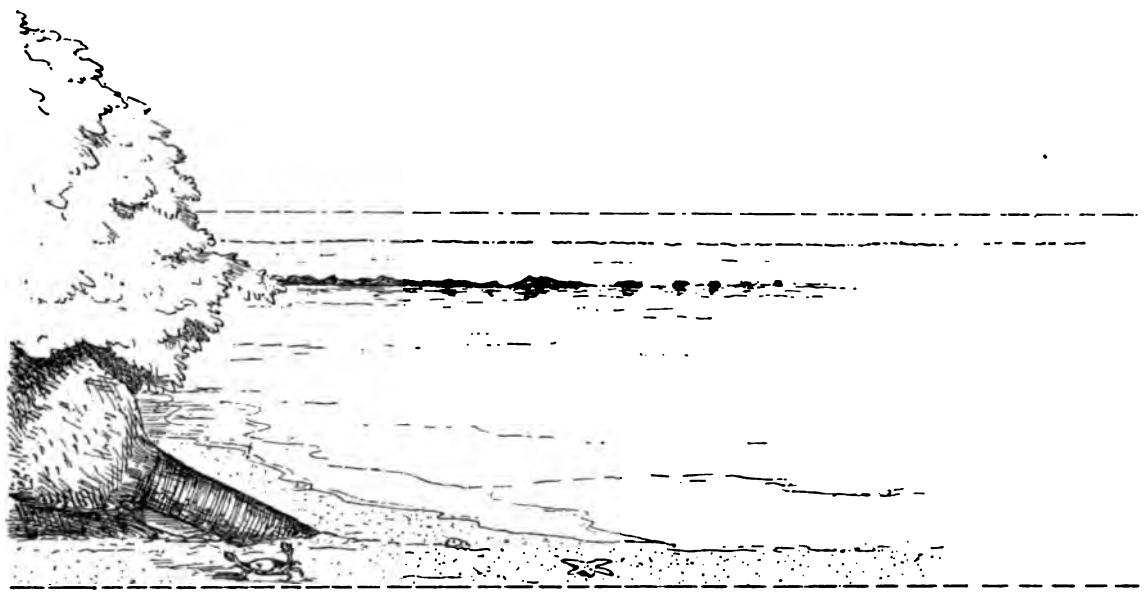


FIG. 91. The reef to the N.E. of Furudu at half tide, looking seaward. The washing away of the land is well seen in the fallen coconut tree and the conspicuous line of beach sandstone extending out from the land.

generally are separated by areas of loose sand. Often, however, the lower terraces lie on the sand-flat quite beyond the slope of the beach, in one place eight separate terraces having been found. The west end of the island is pointed, and the loss in this half is shown on both sides by a cliff with fallen bushes at the top of each beach. At the extreme west point a sand-spit stretches out for 50 yards with a number of sandstone masses along its seaward side and off its

end, showing that the island must have at one time extended considerably further along the reef. Sandstone terraces also occur along the whole of the lagoon beach, but in its eastern half the loss is local, and there is little change at the present time going on at this end of the island. The remains of sandstone lines on the sand-flat at the base of the beach show, however, that in recent years the island extended at the least 25 yards further out on its sand-flat towards the lagoon.

Furudu also is formed entirely of sand, and its north shore lies 80—100 yards behind the boulder zone of the reef. Its beach is coated with sandstone, but the sea has recently broken through this at the east end of the island and washed away much of the sand, so that the trend of the island causes it to be further distant from the reef in this part. The sandstone, nevertheless, still remains as a line of masses, about 90 yards behind the boulder zone. These continue right across to the west end of Fehendu, thus proving the former continuity of the two islands. Further lagoonwards again a series of four sand banks connects the islands, but whether this area was ever covered by the land it is impossible to say. The sand banks and the points of the islands are certainly now growing by the piling up of sand from the lagoon by the winds and waves. Along the south side of the island there is at present little or no change taking place, but a few sandstone masses on the flat off the beach prove that the island formerly extended out further towards the lagoon.

Perhaps the most noticeable point about Furudu lies in its beach sandstone to the north being but little terraced. It presents in many places a cliff of 2 or 3 feet to the sea with one solid mass of rock on the beach behind. This formation is probably due to the protected situation of the island behind the boulder zone and to its situation to the north of the atoll. The sea has not overtopped the sandstone, and its removal must be by the undermining action of the water, both erosion and solution, just as a pinnacle of coral rock is worn away. At the same time the formation on the beach above up to the high tide level must go on, and the sandstone thus necessarily affords very considerable protection to the land.

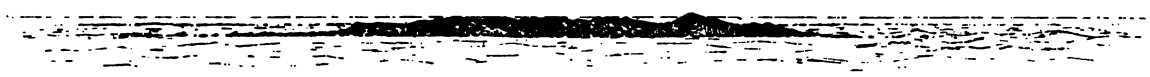


Fig. 92. Fehenfura from the lagoon.

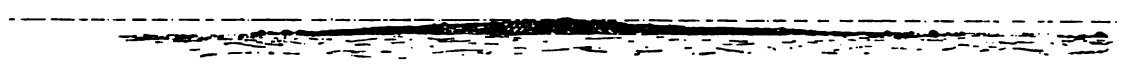


Fig. 93. Mafura from seaward.

Inafuri resembles Furudu—to which it is connected by five large sand banks on the reef as well as by a few sandstone rocks—in its situation in respect to the boulder zone and in being formed of sand alone. It has a terraced sandstone formation on its shores, but this is nowhere extensive and towards the lagoon almost non-existent.

The only other approach to land in the atoll is in two water-swept masses, exposed for 6—8 feet at low tide and stretching for some distance along the reefs on either side of the passage into the lagoon. They are formed of coral rock, and lie on the boulder zone, along which isolated masses continue for some distance at either end. They represent the same line of rock that occurs to the east of Goidu, and, if clothed with vegetation, would be not dissimilar to Raburi and Masilokolu. The natives have definite names for them, that to the east of the passage being called **Fehenfura** and that to the west **Mafura**, and maintain that they were once inhabited land, though they could not produce any evidence in support of their contention.

The reef-flat around the whole atoll is quite similar to that on the west of Minikoi, where no land exists (p. 43). Behind it the boulder zone everywhere continues, consisting mostly of loose masses, but with here and there to the south larger rocks, apparently due to elevation. The whole encircling reef to the south is nowhere more than 500 to 600 yards broad, and to the west appears scarcely any wider. The outer contour of the atoll is almost as drawn in the Admiralty Chart so that, as the encircling reef is charted as very much broader, the lagoon would appear to have enlarged somewhat since the survey. The encircling reef is fringed against the lagoon with living corals, and its edge, like such shoals as arise separately in the lagoon, falls precipitously or even overhangs its base.

II. South Mahlosmadulu (Fig. 94).

Our visit to this bank was made under the most unfavourable circumstances in that

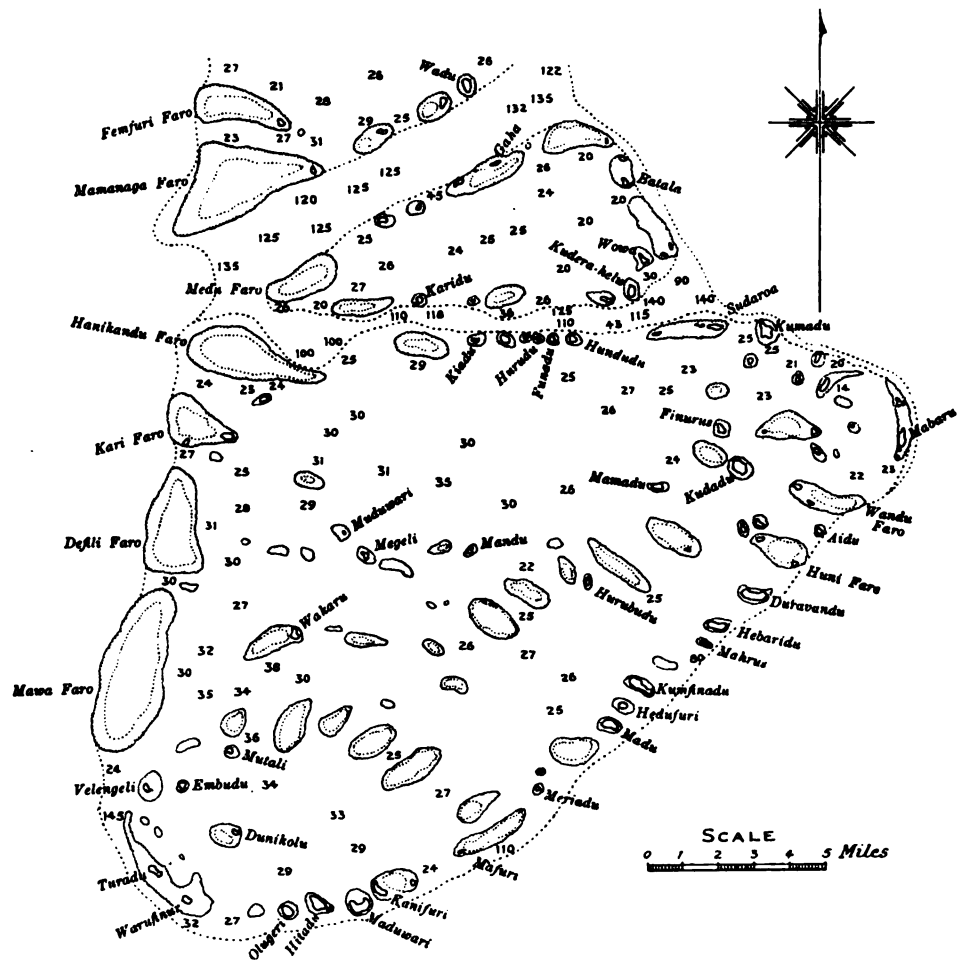


Fig. 94. South Mahlosmadulu Bank (*chiefly from the Admiralty Chart*).

the weather was dead calm during the three weeks we spent in it, and our crew were not as yet accustomed to the working of a schooner. As it was, we commandeered fishing boats

to tow us from place to place, and used the same for visiting the reefs and dredging. Our work, however, had to be largely restricted to a belt 5—6 miles in width along the broad south and south-east part of the bank. The season (Nov. 11—30) was that at the commencement of the N.E. monsoon, when the currents gradually change completely round from about W.S.W. to E.N.E. The current of the N.E. monsoon sweeps through the Kardiva channel with great force, but passes mainly to the south of Goifurfehendu. S. Mahlos is rather affected by that across Fadifolu, and between that atoll and the Miladumadulu bank. A part of this current rushes through the deep channels that divide the whole of Mahlos into three banks, but some sweeps down by Mabaru, and much sweeps over the bank. Currents of 3 to 4 miles an hour were several times registered in the channels near Duravandu, but they are of less importance in the more southern passages. It is possible, however, that in the channels near Hitadu there may be powerful currents in the opposite monsoon. In correspondence with these currents the bottom of the lagoon was everywhere in the part we visited covered with hard sand, singularly barren of organic life. In the passages rock was found either flat or—especially near Duravandu—extremely rough, the dredges constantly catching up in living and dead masses of coral, etc. All this growth of living coral, however, might be, judging from our experiences in other atolls, merely in local, isolated patches, though certainly Mr Cooper's dredgings in the three passages north of Duravandu point to a general upgrowth of the whole rim reef near its seaward margin.

In regard to the land, it is evident that all or most of the reefs of the rim to the south and east had at one time a broad line of elevated rock against the sea. This extended on each more or less as a crescent, the two horns of which curved round for some distance on either side against the dividing passages. Behind this there still exists on most reefs a sandy islet. All such islands on the rim reefs, whether of sand or not, are generally washing away on their seaward faces and growing outwards on their reefs towards the inner part of the bank. On most of the reefs no definite conclusions were possible as to what causes the rock owed its origin, but in Maduwari (p. 163 and Fig. 30) and Hitadu elevation was clearly indicated. Further, no piling up of coral or of other reef material was anywhere found, so that it is reasonable to conclude that the rock everywhere was formed by elevation. The coarse and jagged appearance of the sand grains, that for some distance behind the rocky belt form the land, leads me to believe that the outer parts of the sandy areas of the islands largely owe their existence to the same change of level that formed the rock.

The seaward slopes of the reefs follow the usual form, but the presence of raised rock on the southern reefs, within 40 yards of their seaward edges, shows that their outward growth since the elevation occurred cannot but have been very small. A more marked change may be seen in points from the reefs having grown out into the passages at their seaward ends, the narrowest parts of the channels into the bank and the broadest parts of the individual reefs being generally in this neighbourhood. The bottom off these points is covered with corals, and slopes not more steeply than the reef to seaward. The lines of raised rock pass gradually round on the reefs along the sides of the passages, and do not continue out into these points. It is hence a fair deduction that these points represent a fresh growth since the elevation took place. Further there is every reason to believe that this growth is still going on, and that it will ultimately provide our bank with a complete encircling reef.

As to the lagoon reefs the account given of them in N. Mahlos (Chap. VI.) equally applies to this bank. An unusual feature of the reefs of the islands from Madu to Duravandu is

the gradual slope of their lagoon ends, the depth at about 40 yards from the reef edge in this position being only about five fathoms, whereas off the reefs in the interior of the bank and off the rim reefs in the channels, the general depth in the vicinity—20 *f.* or more—is usually reached in considerably less than the same distance. Further out off the lagoon ends of Mahrus and others of the encircling line of reefs I found no marked steep, and the bottom, so far as I could see, was covered with growing corals and other organisms. The character in these positions was that of a growing reef, and it is this outgrowth, which has built the foundations, on which the islands have become elongated transversely to the line of the edge of our bank. The singularly little growth of these rim reefs to seaward and against the passages is peculiarly interesting, and not easily explicable.

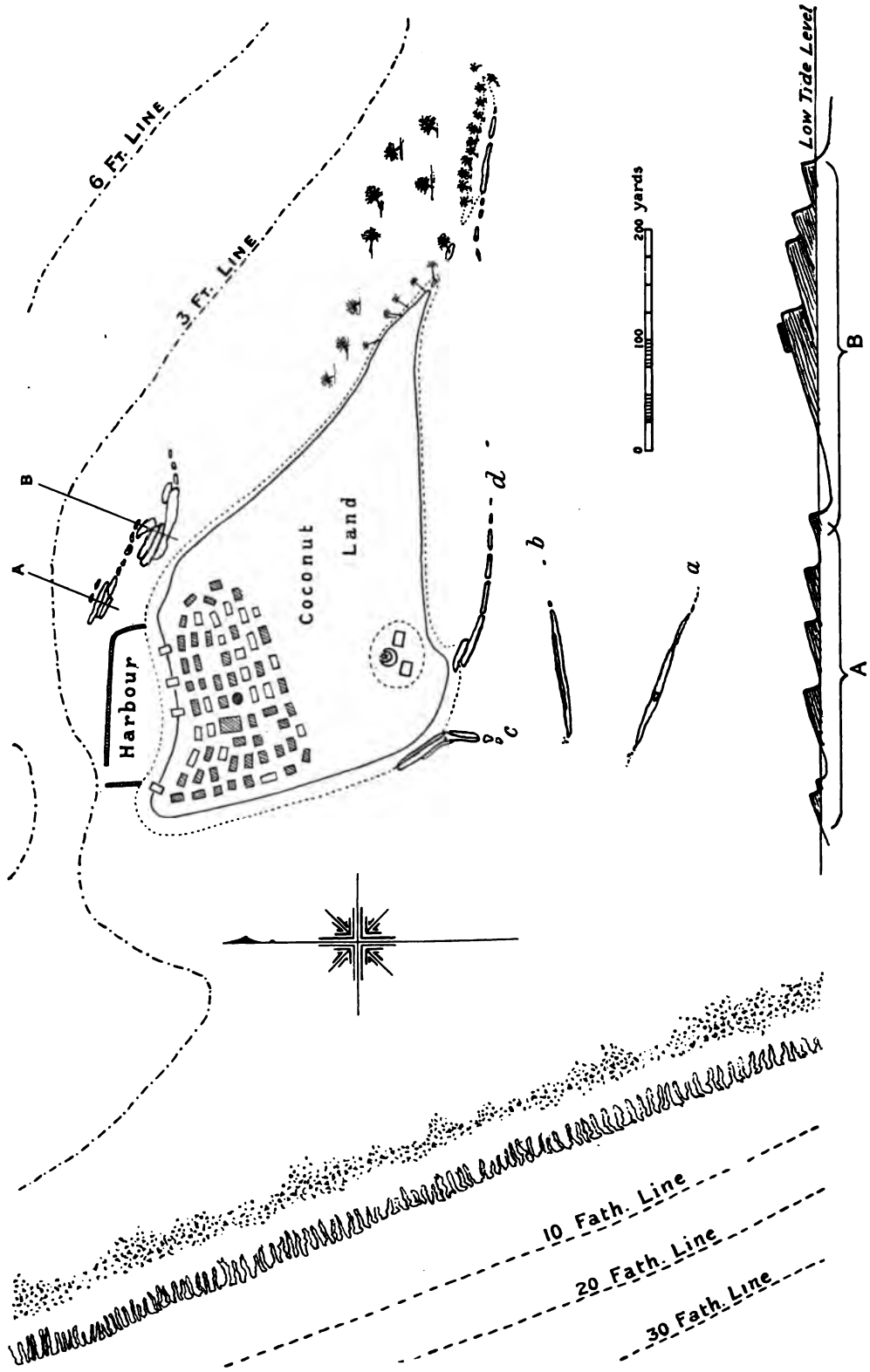
Turadu island (Pl. XIX.) is of especial interest, lying as it does on the south-west corner of the bank, where the greatest force of the S. W. monsoon would necessarily be felt. The island lies about 400 yards back from the seaward edge of its reef, and is entirely of sand formation with no trace of coral rock on any of its reefs. The seaward reef has a well-defined edge, reef flat of 40—50 yards, boulder zone of 20—30 yards, and sandy boat channel with 1—2½ feet of water, which continues round the other sides of the island in a sandy flat. The latter, however, at the extreme north point is scarcely existent, the shore sloping evenly to three fathoms in about 50 yards.

The island has in recent years been struck by two cyclones, "at the commencement of the S. W. monsoon"[1] of 1896, and in August, 1898. The former is said to have swept down along the island from the N. W., while the greatest force of the latter was experienced at high spring tide from the S. W. The combined result of the two has been to reduce the island by more than the half of its former size. Yet, it is quite evident that destructive forces were at work long antecedent to these gales, a few odd sandstone rocks on the reef to the south indicating that Turadu and Warufinur were once nearly or quite connected.

The chief characteristics of the island may best be seen in the accompanying Chart (Pl. XIX.). It now nowhere attains a greater height than 4½ feet above the high tide level, and shows loss on every side except perhaps at the N. W. point, and for about 150 yards down the W. side. The sandstone rock to the N.E. exhibits nine terraces (sections A and B), while on the beach behind a tenth is forming between the low and high tide limits. The layers have evidently been much worn down, and are hollowed out underneath; the lower ones are markedly less consolidated than the upper, and serve to fully confirm the account of the rock given in Appendix A. The different lines of this rock in the boat channel on the south side are separated by about two feet of water at low tide, and serve admirably to show the former contour of the land. The outer line *a* has traces of five terraces, but *b* of only two; the average height of each above low tide is about 15 inches, but *a* has a single undermined mass in the centre, which stands up for 3 ft. 5 in. and is about 8 sq. yds. in extent. *c* is the continuation of a firmly consolidated line of sandstone on the beach to the north of the last, which formerly extended between the low and high tide levels. The sand on the beach above it was scooped out for 8—10 yds. in one of the recent cyclones, but has filled in again. *d* is a breakwater piled up on the top of a more recent and less consolidated line of sandstone. Its position represents the direction of the beach before the cyclone of 1896 (?1898), and behind it in the small bay is an incipient formation of rock.

The S.E. half of the island runs out into a point, beyond which a sand bank shows clearly the direction of the island for a further 193 yards. It has along the middle of its south side a line of sandstone, which runs as if to join *d*; it evidently belongs to the same formation as *d*, and the complete line shows on this side of the island the destructive action of the two cyclones.

[1] The description given by the natives.



TURADU ISLAND AND REEF.

(*From the author's survey.*)

To face p. 382.

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Turadu island (Pl. XIX.) is of especial interest, lying as it does on the south-west corner of the bank, where the greatest force of the S. W. monsoon would necessarily be felt. The island lies about 400 yards back from the seaward edge of its reef, and is entirely of sand formation with no trace of coral rock on any of its reefs. The seaward reef has a well-defined edge, reef flat of 40—50 yards, boulder zone of 20—30 yards, and sandy boat channel with 1—2½ feet of water, which continues round the other sides of the island in a sandy flat. The latter, however, at the extreme north point is scarcely existent, the shore sloping evenly to three fathoms in about 50 yards.

The island has in recent years been struck by two cyclones, "at the commencement of the S. W. monsoon"[1] of 1896, and in August, 1898. The former is said to have swept down along the island from the N. W., while the greatest force of the latter was experienced at high spring tide from the S. W. The combined result of the two has been to reduce the island by more than the half of its former size. Yet, it is quite evident that destructive forces were at work long antecedent to these gales, a few odd sandstone rocks on the reef to the south indicating that Turadu and Warufinur were once nearly or quite connected.

The chief characteristics of the island may best be seen in the accompanying Chart (Pl. XIX.). It now nowhere attains a greater height than 4½ feet above the high tide level, and shows loss on every side except perhaps at the N. W. point, and for about 150 yards down the W. side. The sandstone rock to the N.E. exhibits nine terraces (sections A and B), while on the beach behind a tenth is forming between the low and high tide limits. The layers have evidently been much worn down, and are hollowed out underneath; the lower ones are markedly less consolidated than the upper, and serve to fully confirm the account of the rock given in Appendix A. The different lines of this rock in the boat channel on the south side are separated by about two feet of water at low tide, and serve admirably to show the former contour of the land. The outer line *a* has traces of five terraces, but *b* of only two; the average height of each above low tide is about 15 inches, but *a* has a single undermined mass in the centre, which stands up for 3 ft. 5 in. and is about 8 sq. yds. in extent. *c* is the continuation of a firmly consolidated line of sandstone on the beach to the north of the last, which formerly extended between the low and high tide levels. The sand on the beach above it was scooped out for 8—10 yds. in one of the recent cyclones, but has filled in again. *d* is a breakwater piled up on the top of a more recent and less consolidated line of sandstone. Its position represents the direction of the beach before the cyclone of 1896 (?1898), and behind it in the small bay is an incipient formation of rock.

The S.E. half of the island runs out into a point, beyond which a sand bank shows clearly the direction of the island for a further 193 yards. It has along the middle of its south side a line of sandstone, which runs as if to join *d*; it evidently belongs to the same formation as *d*, and the complete line shows on this side of the island the destructive action of the two cyclones.

[1] The description given by the natives.

The latter is also shown by the whole sand flat behind this line being strewn with the remains of fallen coco-palms and bushes. Behind the sandstone of the S.E. bank a few bushes of *Pemphis acidula*, their roots washed with every tide, continue to exist, but the sand flat to the N. is studded with their gaunt stems, which even yet have not decayed and fallen. The same kind of bushes also grows down on the beach along the N. half of the N.E. side of the island, forming some protection to the land, but the sea has broken through the line to the south, and is now slowly but surely rounding off the point.

The whole changes at Turadu serve admirably to illustrate how great may be the action of the sea in a very short period of time. The separate lines of sandstone, however, point to the fact that such action is succeeded by prolonged periods of rest or little change, the land being almost as efficiently protected against the ordinary weather by the formation of the beach sandstone as by a line of coral rock. Nevertheless, the possible effect of a cyclone is perhaps more far-reaching as effecting the cleaning out of boat channels, sand flats, etc. The absence of sedentary life between the land and the reef at Turadu was remarkable, even the ordinary *Madrepora*, *Porites*, and *Psammocora* being absent. It was noticeable further that all coral and similar growth on the sand flat towards the lagoon—while, to judge from the dead colonies, formerly plentiful for such a position—had been killed. Even at the time of our visit there was a considerable flux along this side of the island, which would prevent the formation of fresh growth and render easy the enlargement of the lagoon.

In the whole reef on which Turadu is situated I could find no definite faro-formation. The lagoon reef of the Admiralty Chart does not exist as a definite line, in many places the slope off the sand flat of Turadu island being perfectly even to 18 fathoms, the maximum depth found towards Dunikolu. There are, however, a series of reef patches along its line, showing that it was not improbably quite correctly placed when the survey was made.

Dunikolu is a sandy island of slightly crescentic shape, lying along the E.N.E. side of a faro. The island is growing to the N., S. and E., but slightly washing away on the side of the velu. The whole encircling reef is covered with about one foot of water at low tide. To the E. it has outside the island, which is about 100—150 yards back, a distinct boulder zone, beyond which lies a flat covered with living corals and apparently growing outwards. No trace of any particular connection or of any shoal water between this reef and that of Turadu was found.

Embudu is a sandy island with a definite reef, which is on all sides at the least 100 yards broad. The beach N. and S. presents terraces of sandstone with a cliff above and in places fallen shrubs, but to the E. and W. the land seems growing. In the centre the island reaches a height of nine feet above the high tide level, the sand having been piled up by the wind.

Velengeli lies to the S. W. of a considerable shoal, opposite an extensive opening in the rim of the bank to the N. of Turadu. This channel is one of the chief passages, by which the current passes on to and escapes from S. Mahlos, and any shoal in its centre would be fully exposed to the force of the S.W. monsoon. As a result the reef presents to seaward quite the character of the regular encircling reefs, and it also has a distinct though less marked flat and boulder zone to the E. as well. The island is pear-shaped, a broad head to the west tailing off to a point to the east. It is formed entirely of small coral stones, their interstices filled in by sand, and is rather lower in the centre. It is highest at the W. end, which absolutely lies on the boulder zone of the reef, and here a series of ridges may be found due to pilings up of small stones by successive gales or cyclones. These ridges to a certain extent increase in height to the outside, and suggest a correlation with the distance of the land from the edge of the reef. Any change in the island at present is local, one mainly of gain rather than of loss, but such as there is is slow and inconsiderable.

The beach to the S. and N. of Velengeli shows a most interesting formation of rock, reaching up to the high tide level. It is a true beach formation, but consists of coral fragments, many

rounded, that have become firmly consolidated by sand and deposited carbonate of lime. In places it is being worn away and pinnacles of it left on the reef or sand flat. In their composition the rock masses simulate coral rock, but their surfaces are much more rounded and their corals are seen at the first glance not to be in the position of growth, and are mostly small broken masses.

Mutali is a sand bank, similar to Embudu, washing away slightly N. and S. but growing out in spits to the E. and W. **Mawa Faro,** which I saw only at high tide, does not differ materially from the Chart, save that its velu extends much further N. and S. and its E. reef is quite narrow. **Warufinur** lies on the Turadu reef, but further back from its seaward edge than that island. It is of sand formation, growing out N.W. and S.E. in sand spits, otherwise showing little or no change.

Hitadu is a sandy island, more or less triangular in shape, with a narrow base to the S.E. Its southern reef is about 130 yards broad, and there are on it two rocky islands to the S.E. and S.W. The appearance suggests that Hitadu is the remains of a much larger island, almost conterminous with its reef to the S. At present its shores show little signs of washing away, but on the contrary it is clear that the pointed N. end of the island has grown out considerably in recent years. **Olugeri** has a rocky beach everywhere and covers the greater part of its reef; its vegetation consists of high timber, the abode of the Lesser Frigate Bird, *Fregata ariel.* **Kanifuri** I did not visit, but its shore to the S. and S.W. could be seen in passing to be rocky, with bare tree trunks and a little fallen timber.

At **Maduwari** (see p. 164, and Fig. 30) I would draw attention to the line of coral rock, protecting the land to the S. and curving round on the reef. The prominent horns of the reef growing out into the passages on either side, together with the lie of the elevated rock, serve admirably to illustrate my contention that the reefs against the passages are growing out to meet one another, ultimately to form a single encircling reef to the bank.

Kudadu (the E. island on the Kanifuri reef) and **Mafuri** are both of sand formation. The former has an extensive formation of beach rock to the N., but the latter is only a tiny bank with two bushes of about 20 feet in height. The **faro to the north** of Mafuri had a large sandy islet, but now has no sign of the same; its velu, too, is much larger. **Mandu** is a regular, sandy islet, little or not at all changed, but the pair of reefs to the S.E. are well marked with large velu and with no 'Sandy Isles' nor 'Stony Islet.'

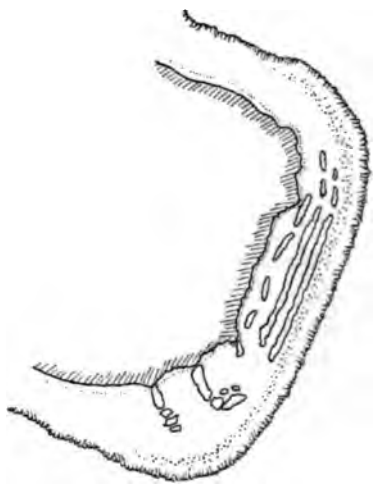


Fig. 95. The S.E. end of Madu, showing the lines of coral rock.

Madu, while mainly a sandy islet, has a broad rocky belt on its S.E. end (Fig. 95). The reef here is about 100 yards broad from the low tide level on the beach to its outer edge. The reef slopes comparatively gradually outside, the sea 40 yards out from its edge being only about 2 fathoms in depth. The reef flat is about 60 yards broad, and there is within it a much broken area covered with large masses of coral rock, which roughly speaking form three lines, a fourth being found in the base of the beach. Other masses also occur where the shore of the island bends round N. and S. towards the lagoon. The rocks to seaward show that the land once extended to within 30 yards of the present reef edge, so that the outward extension of the latter can have been but very small since the elevation that formed the land. As the rock passes into sand round the sides of the island a few lines of beach sandstone run out from the shore, but there is little or no erosion going on at the present time. On the other sides of the island the reef edge is at least 100 yards distant, and has within it a shallow boat channel of 1—2 feet.

Hedufuri is entirely a sandy island with broad beaches and reef edge 80—200 yards away, with a narrow sandy channel of 1—2 feet. The reef on the seaward side has a few rocky masses, so that the land would seem to have at one time extended nearly to this edge of its reef. **Kumfinadu** is a long, sandy island running out into a rocky point at its seaward end (Fig. 96). Here the island stretches out on to the boulder zone, the edge of the reef being only about 35 yards from the shore. The rock extends for about 70 yards behind the point, and on the reef continues round its seaward end in a series of pinnacles and masses on the boulder zone. Behind these the land shows rapid loss, but against the passages, although beach sandstone may occur, there is otherwise little change; towards the lagoon a sand spit is, if anything, growing out along the reef.

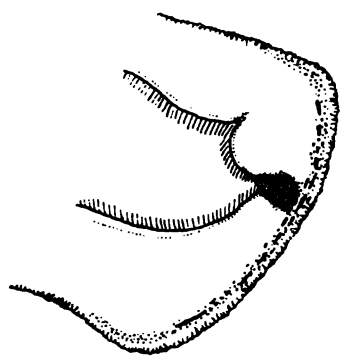


FIG. 96. The seaward end of Kumfinadu island, showing the rocky point and pinnacles of rock extending round the reef.

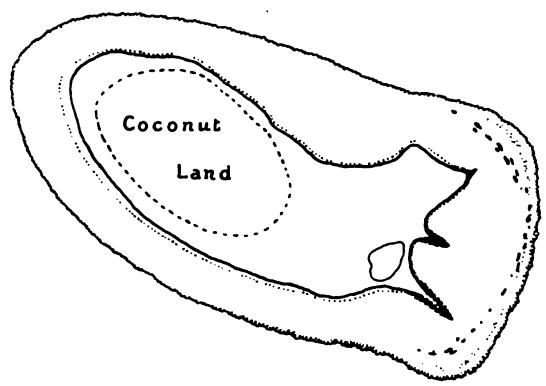


FIG. 97. Hebaridu Island and reef.

Hebaridu is on most sides at least 200 yards distant from the edge of its reef (Fig. 97). It is formed of sand, and has three spits marked by beach rock extending out to the east. Round this end, particularly in the N.E. corner, the reef has a series of large coral masses in and behind its boulder zone, that seem to have once formed part of the land. **Mahrus** is built up entirely of sand. It is larger than shown in the chart, and in shape roughly oval with a point to seaward, on which are some fallen shrubs and much sand rock. The reef to seaward is about 120 yards broad, and is characterised by its square end. From this the reef slopes inwards, so that its broadest part is that which lies directly against the sea. Round the lagoon half of the island the reef is very narrow, not attaining a greater breadth than 40—50 yards.

I have already referred to the sandstone found on the shores of **Duravandu,** another sandy island (p. 345). It occurs principally along the E. and S. sides, the island otherwise showing little change. The reef off the seaward end is about 200 yards broad, and has a well-defined boat channel. In other respects the island and reef do not differ from the last described. **Aidu** is an oval-shaped island with a crescentic belt of rock around its E. end, the rest of the island being of sand formation. As usual there is washing away on the seaward end and growth towards the lagoon. The **Mabaru** islands show that they were once connected together, lines of sandstone extending out along the reef between them. There are also the remains of an outer line of coral rock along the seaward part of their reef. Mr Forster Cooper, who alone visited this corner of the bank, was of opinion that the sandy area of the original island was formed by a series of gales or cyclones having heaped up the sand on the reef from its lagoon side. Each storm formed a ridge of sand, and the island accordingly was extended lagoonwards by a series of leaps alternating with periods of rest.

In the N.E. part of S. Mahlos there seemed to be so little change within the lagoon that references to individual reefs are unnecessary. All the islands are of sand formation, here and there losing or gaining. Usually there is a well-marked ridge of sand above the beach, blown up by the wind. A reef 40—80 yards broad commonly surrounds the land. It may have a boat channel, a few feet deep, inside, but the outer part is as a rule rather loosely built up of coral.

Kudera-helu *belongs rather to the intermediate area of Mahlos*, and is a sandy island, which has little changed in the last few years. It is surrounded by a reef 60—150 yards broad, having a distinct reef flat, boulder zone, and boat channel on each side with a few pinnacles, apparently of the elevated coral rock, still remaining. **Batala** is now a faro with a velu of about 4 fathoms to the N. The former single island to the south has become cut into two parts, a rocky island on the S.E. of the reef and a sandy one behind.

III. North Mahlosmadulu (Pl. XI.).

In every part of this bank changes of some sort or other were found, but most have been already dealt with in Chapter VI. The details about additional islands and reefs on the bank, that I could add to that account, in every way accord with the conclusions therein reached. I have, however, considered both the reefs showing the most striking changes and conditions and those which are least changed, so that with the exception of a reference to a few particular islands and reefs to illustrate special points no further account is necessary here. Among the following notes those about Rasmadu, Duwafuri, and Hudufaro I owe to my companion Mr Forster Cooper.

Rasmadu island lies E.b.N. and W.b.S. It is considerably broader at its E. or seaward end, which is protected by a line of the elevated coral rock from the encroachment of the sea, the rest of the land behind this line of rock being formed of sand. The solid rock forms a belt on the beach, and is topped by a line of boulders, piled up from the same, but somewhat admixed with sand. To the E. the edge of the reef is 50—60 yards distant from the base of the beach. The reef broadens by the sides of the island, but the widest part of the whole shoal is near its seaward end. The S. side of the island has much beach rock, but the N. shore is formed of loose sand with a single patch of sandstone near its lagoon end. The W. end of the island is growing outwards into the lagoon; it has a broad beach of sand and stones, the latter provided by the rock on the sides of the island as well as by the sweepings of the reefs. The muddiness of the water after moderately heavy N.E. winds was especially observed by Mr Forster Cooper. It seemed to be due to the washing out of the sand from a narrow boat channel of 2—3 feet which extends nearly round the island.

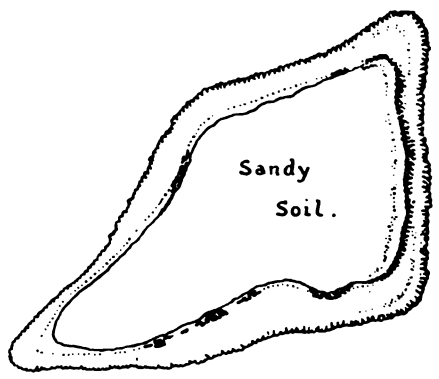


Fig. 98. Rasmadu Island and Reef.

Duwafuri shows considerable changes in that the large island, which is built entirely of sand, has sent out a long narrow spit towards the small island marked on the N. of the reef. The latter islet is now a mere patch of rock, over which the water sweeps in rough weather when the tide is high. The reef to the E. is nowhere less than 100 yards distant from the land, and has the regular reef flat, boulder zone—which is continuous with the N. islet—and boat channel, the latter with

a depth of 3 feet. To the N.W. of the island is a broad pool with an average depth of 1 fathom, but approaching 2 fathoms in the centre. The W. side has a broad, sandy beach, the change in which, if there be any, is one of gain rather than loss. To the S.S.E. a sand spit has been formed running out to within 20 yards of the boulder zone, which in this position is marked by the piling up of a stony patch.

The E. side of Duwafuri is remarkable even in the Maldives for its extensive loss. In the first place about 200 yards to the S. of the northern, sandy, outgrowing spit is a line of beach sandstone terraces, dipping to the N. and running right out diagonally nearly across the boat channel. This rock probably shows the former contour of the island before the sand spit grew out, the island possibly of Moresby's Chart. South of this the E. side is literally covered with fallen coconut and other trees, with here and there patches of the beach sandstone, the rock not generally in terraces and as yet in most places ill-consolidated. Many of the root masses of the dead trees still lie in the water below the low tide level—the island is not inhabited or they would have been removed by the natives for firing—one even being 80 feet out from the present shore. In one place a soft beach sandstone had absolutely formed round the trunk of a coconut tree before the latter had had time to rot, a period probably of less than 20 years.

Hudufaro (Hee-fur-ru of Chart) shows almost the same changes as the last island in a marked washing away of its E. or seaward face, little or no loss or gain to the W., and a possible growth outwards to the N. and S. The E. side has an extensive formation of sandstone, of which lines are found in a boat channel of 80—100 yards broad between the boulder zone and the beach. One line in particular was of interest near the N.E. corner of the reef, where the erosion was especially rapid; it runs out diagonally across the boat channel, ending in some masses just behind the boulder zone. No pinnacles, which could be definitely said to belong to the elevated rock, were found.

Off **Raskateen** the reef is only about 60 yards broad to the E. but it gradually increases in width around the island, to the W. being 120 yards across and having a small boat channel. To the N., E. and W. the island shows no change, but to the S. there is an outgrowth of sand. Everywhere the beach is formed of sand except to the E., where there is a mixture of sand and rock, the latter mainly the washed-out coral masses of a former line of the elevated rock. The island is peculiar in that it is surrounded by a belt of higher land, about 50 yards broad by 7 feet above the high tide level, while its central part is 3—4 feet lower.

Wadu is noticeable like most of the other islands of the rim for the extensive erosion of its E. or seaward side, the land even where the reef is narrowest lying 200 yards behind its edge. It is still more peculiar for the enormous breadth of its W. reef, 300—400 yards, a width quite unparalleled along the east side of N. Mahlos. Such growth of land as is now taking place is to the N.E. along the sandy belt between the velu and its seaward reef. The presence of a rocky island to the N. and a few rocks along the seaward side of the middle part of the reef point to the former existence of a single elongated island, before the faro formation took place.

Of the islands of the W. side I find on reference to my note-book that the statement (p. 169) that **Maregiri** is a sand island is not quite accurate. Much sand enters into the composition of the island in every part, but only the E. half is formed entirely by it. The western third has its beaches mainly formed of coral rock and loose blocks of stone, and the intervening part is intermediate. The rock, however, only forms a belt around the W. end, the middle of the island being formed entirely of sand. At the S.W. point the reef is 150 yards broad, and is studded for its inner 90 yards with pinnacles of coral rock, into the composition of which sand especially largely enters. Originally there would seem to have been a broad crescent of coral rock round the W. end of the island, but no traces of this are to be found within 40 yards of the outer edge of the existing reef, which I suppose to have grown out since the elevation for the greater part of this distance. The loss of land along the W. and S. sides is shown by the rock,

as well as by sandstone in the beach to the S. To the N. there has been much washing away in the past, but along the W. half of this shore there is now some piling up of coral masses, etc., these in one place overlying a line of beach sandstone. The E. end has no definite reef, sloping gradually to 17 fathoms, with a sandy bottom on which a few coral colonies here and there manage to live. The presence at this end of the island of an upper sand cliff of 2 feet, separated by a terrace 60 yards broad from a lower fall of 4 feet, possibly indicates a washing away. The terrace, however, does not seem to have ever been covered with vegetation, and was formed, I am inclined to consider, by a piling up of the sand in recent times.

Mudduwari has large beach sandstone masses E. and W. and a rocky island covered with trees to the S., evidently a very few years ago—the natives say 30 years—joined to the main island. Round the whole reef are a series of masses of the raised rock, showing that the original island was nearly conterminous with its reef. The large island is built up entirely of sand, but this a few feet below the surface is so coarse and sharp-angled that it would scarcely seem to have been washed up by the sea. (See also p. 165.)

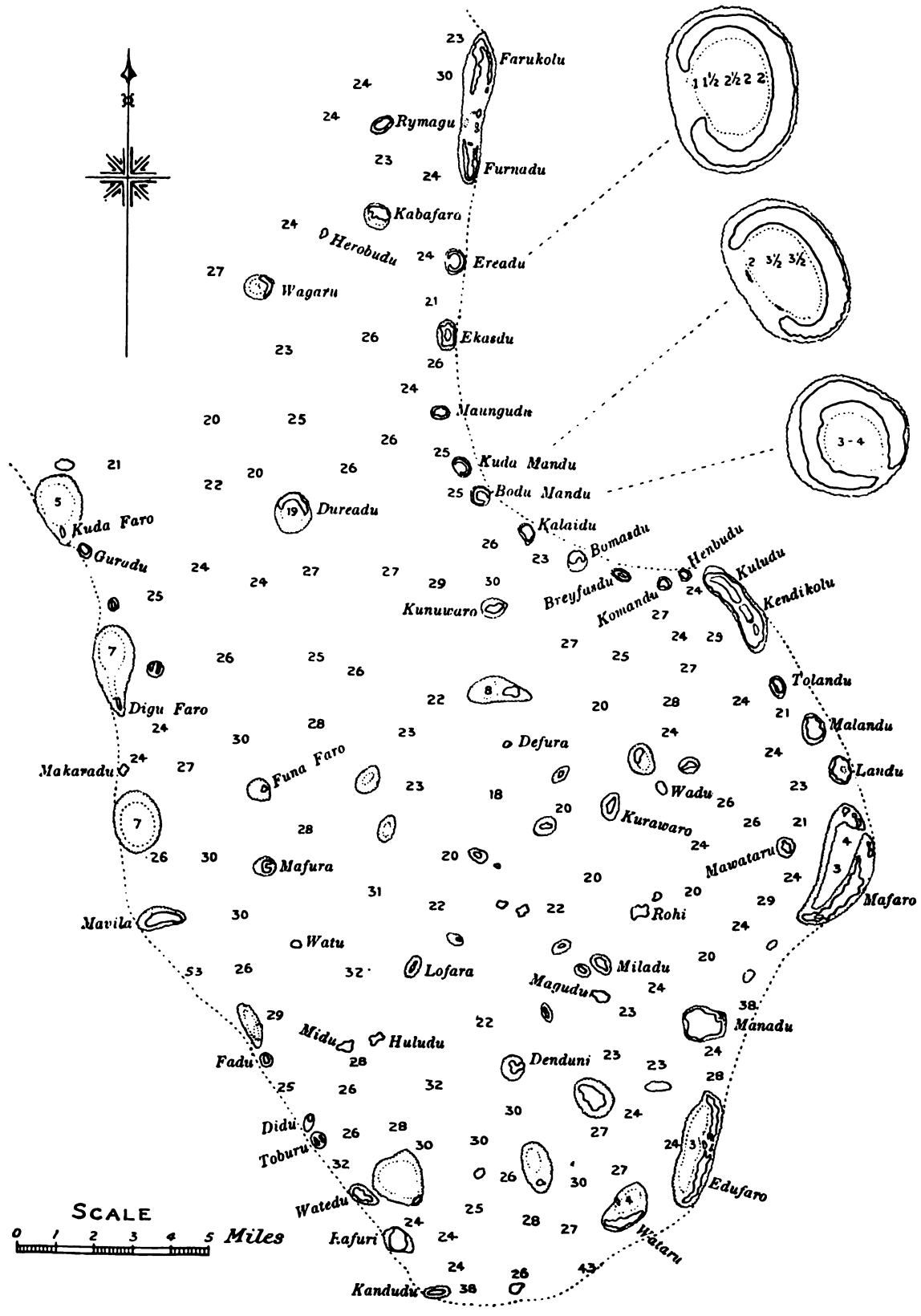
Fusmundu besides its velu is remarkable for the washing away of the shore and the formations of sandstone to the S. and S.W. The islet is composed entirely of sand, and both land and reef appear to be growing out to the east, the reef in addition having a point to the west. The reefs N.W. to **Kutal** all seem to be to some extent growing out in the direction of the current; most have some sort of a velu. On the larger are found at their seaward ends between tide marks broad boulder zones of recent formation, almost "stony patches."

IV. Miladumadulu (Pl. XX.).

This bank is arbitrarily divided for governmental purposes into two parts, to which are given different names, Tiladumati and Miladumadulu, but between which there is no geographical separation. The whole bank differs from all other Maldivan ones in its islands being so widely separated from one another that in all, or nearly all, parts almost oceanic conditions prevail. Yet, owing to the water passing for some distance over a bottom of decreased depth, there has been developed a certain amount of difference between the seaward sides of the rim reefs and those which face towards, or rise upon, the centre of the bank. Against the sea heavy breakers are found, while within even the most open part of the bank they are never of any importance. Such breakers would imply strong under-currents outwards along the slope of the reef (see p. 24), while owing to the shallow depths on the bank the currents simply diverge on either side of any reef. The plankton crossing the surface would be plentiful enough, but might not be suitably distributed by the currents over the bank. Again, the water outside would be clearer and more charged with carbonic acid gas, the main food of reef corals and nullipores, while, after crossing any part, it would be bound to have picked up some amount of dirt, and much of its carbonic acid gas would certainly have been used up and not replaced. The extremes of temperature are more widely separated upon the bank, but, the average being about the same, it is difficult to see that this circumstance could have much effect on the growth of the organisms.

Nevertheless, the openness of the rim of Miladumadulu must be of some considerable importance, since it was only[1] on this bank that we found the existence of a definite reef flat off any of the central islands, together with a well-formed fissure zone and gradual slope outside to the general level (*vide* Dureadu below). Alone in the interior of this bank also

[1] N. Mahlos is to some degree an exception (see Chapter VI.).



MILADUMADULU ATOLL WITH ENLARGEMENTS OF SOME OF THE ISLANDS.

(Somewhat altered from the Admiralty Chart.)

To face p. 389.

I have found *Lithothamnion* to be abundant on the edges and slopes of the reefs, but it does not incrust large areas, as on the true seaward slopes. Off the west of many of the east rim islands no reef flat occurs, but this is easily explicable by the consideration of the recent changes in the land, such absence of reefs being usually associated with an outgrowth of the land by the piling up of sand, or in other words with much movement of fine matter by the winds and waves.

As a whole our bank is a table-land beneath the sea with a number of gradually, or precipitously, sloping, low table-hills, all of the same height. Its interior is remarkably level, and, while there is generally a little sand covering the surface of the bottom, our sounding leads never drove into a thick deposit except close to some island. In dredging we procured a number of corals, especially near reefs, but more often the dredges came up with polished metals and quite empty. Between the islands of the east rim the bottom was rougher, and we obtained specimens of most of the sedentary animals found elsewhere in 20 fathoms. Between Mafaro and Manadu we found two coral patches of 7 and 10 fathoms, but within the bank we met with no areas which seemed to be growing up to form surface reefs.

How the islands within the bank were built up in the first place is not at all clear. In any former condition of the bank there is no reason why shoals should not have grown up on any part, provided the reef corals and other organisms once managed to obtain a firm foothold. An island like Dureadu with raised coral rock outside could only have been formed by a change of level. But the large majority of the inner islands are formed of sand, perhaps indeed all those charted as without any reefs, this absence of foundation reefs being due to the movement of the sand on their slopes preventing any growth of rock-forming organisms. Further, all these sandy islands appear to have their shores washing away, and how they have continued to exist so long it is difficult to explain. They would necessarily seem to have been created in the first place by a change of level, but the original shoals must have been built up of rock rather than sand. Not only are these islands themselves washing away, but, since they have no enclosing reefs or protecting growth of organisms on their slopes, their foundations are being removed down to the level of the floor of the bank. It accordingly appears probable that the sandy islands were formerly protected by belts of elevated rock against the sea, which have now been completely removed, but the evidence, from which their former condition might be deduced, is very meagre.

It is most extraordinary that all the banks of the east rim should have land. Round their seaward sides the reef flats are in all cases very narrow, and the islands would appear to have been at one time almost conterminous with their reefs. The seaward beach is in every case of rock, and the reef flat off the same is studded with pinnacles and masses of rock; its surface and edge are bare and it shows no definite outgrowth in any place. Where there is no land, as in the middle of the reef of Furnadu and to the north-east of Mafaro the reef flat is broader, and the reef has the regular fissured edge characteristic of an outgrowing one. Accordingly, the absence of outgrowth off the land must be ascribed to the mud and dirt which is being continually swept out from it, preventing the growth of the building organisms. To the west of the same rim reefs, wherever a definite flat exists, its edge has the usual outgrowing appearance, but owing probably to the shallower water this is often more marked than to seaward. As already mentioned, a true reef is, however, seldom found off the inner ends of the islands of the east rim, owing to the currents forming eddies behind their reefs and constantly shifting the sand.

The presence of pools of more or less fresh water in many of the east rim islands is remarkable. All such must have been at one time connected with the sea, as they all have fish and prawns identical with, or closely allied to marine species. In addition their shores are fringed with mangroves, which could only have been introduced when their waters were in open communication with the sea. Some of these pools were perhaps cut off by sand being piled up on their lagoon sides, in particular those with shallow water in Ekasdu, Kendikolu, and Landu seeming to have been formed in this way. The size of the islands and the fact that the sand, instead of being piled up directly against the rock, was deposited at some considerable distance out on the reefs, thus cutting off pools of water, allow us to infer that the original reefs before elevation were flats of considerable breadth. Further, the deeper pools of Ereadu and the two Mandu, so greatly enclosed by land as they are, are not likely to be of recent formation, so that some of the reefs before elevation were probably themselves definite faro. A still more remarkable reef is that of Dureadu with its velu of 18 fathoms, but the weather—and want of drinking water—prevented a thorough investigation of this faro.

The condition of the Miladumadulu-Tiladumati bank is quite unparalleled elsewhere in coral reef regions, and its topography would be almost inexplicable if it had been examined alone. The bank compared with North Mahlos and others shows that it is only an early stage of atoll formation. Nevertheless, many points in Miladumadulu are not clear, but it is probable that Prof. Agassiz with a more complete examination extending into Tiladumati and to deeper depths outside the bank will be able satisfactorily to elucidate these.

Guradu has on all sides stony beaches with coral rock. To the N.E. there is practically no reef, the same condition being found as to the N.E. of Minikoi, where the waves break about 20 yards from the shore. This condition merges on either side of the island into a definite fringing flat, to the S.W. 50 yards across. The shore, S. and E., has many large dead tree trunks, and on all sides masses or pinnacles of the coral rock were seen. The island on **Kuda-Faro** is all sand, and situated well behind its reef, which is a faro with well-marked velu.

Dureadu is a crescentic-shaped island, covering almost half the circumference of a round faro, 1¼ miles in diameter. The beach against the velu is all sand, the top about 2 feet above the high tide level. It shows much movement, its sand apparently shifting to the W. in the S.W. monsoon and to the N.—and probably N.E.—in the N.E. monsoon. On the whole there would appear to be a little loss as there are a few fallen trees, etc. A sand flat, narrower to the N., fringes the shore against the velu, but the term sand flat is here a misnomer, the shelf having a mere covering of sand on a solid rock, which round the ends of the island—to the S.W. being 60 yards broad—forms a continuation of the reef flat. Within the crescent on the flat there are no corals, but a few shoals built up of their colonies are found in the velu. Twelve soundings on the submerged reef to the S. gave depths varying from 3 to 5½ fathoms, so that probably there has been little or no change. I could not see the character of the bottom on account of the heavy weather having made the water quite milky.

To the N.W. of Dureadu I. on the outside is a shallow, incipient bay with sand shores and a reef 120 yards broad, consisting of a flat, boulder zone and boat channel—that is, of the same parts as on any rim reef freely exposed to the full force of the ocean. In the boat channel and on the boulder zone are a few masses apparently of upheaved rock. These are rather more numerous to the S.W. and to the N., where the island runs right to the boulder zone of the reef, and has a rocky belt along its shore. To the N.N.E. there is simply a reef flat of 25—30 yards in breadth, quite similar to any seaward one, save that it is without the regular fissured and buttressed edge, but

these parts are also absent off many of the E. rim islands of the same bank. On its inner part lie many flattened dead slabs, the bases of large colonies of *Madrepora*, merging above into the beach, which is partially composed of them and partially of the raised rock. No part of the latter attains a greater height than that of the high tide level, but the loose masses on the top of the beach form a narrow ridge about 10 yards broad and 2 feet higher. Behind this again the surface of the land is a little below the high tide level, and hence, being moistened with every tide, supports a mangrove swamp. The breadth of the island in the middle of the N. side is 230 yards, of which the belt of rock occupies the outer 60—70 yards.

Rymagu is surrounded by a definite reef flat, 20—40 yards broad and formed of rough coral rock, completely exposed for about 1 foot at low tide. This possibly extends under the whole island, for I was informed that the wells all pierce the rock, this perhaps accounting for their relatively excellent water. The island is mainly formed of sand, but its shores have a certain amount of boulder material from off the flat.

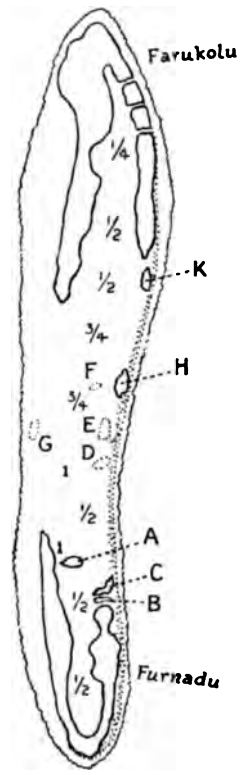


Fig. 99. Furnadu Islands and Reef.

The **Furnadu** reef has two U-shaped islands with their open ends facing one another. The conditions are most readily seen by the examination of the accompanying map (Fig. 99), a comparison of which with Moresby's chart is interesting. In the first place it may be noticed that the seaward limbs and those parts of the islands, which lie to the N. and S. of the reef, are of rock, while the areas against the interior of the bank are built of sand. On the outer shores of the islands off the rocky parts the reef is narrow,—nowhere more than 50 yards across—and there is a little washing away, whereas against the sandy parts there is a broad reef with no sign of loss in the land, but, if anything, a gain especially of the projecting points. On the inner shores of the islands on the contrary we found everywhere a considerable loss, most obvious in those parts to which the sea can readily find access, the innermost shores being in addition protected by mangrove swamps fringing the land.

Of the new islands that marked *A* has been formed by the washing away of the W. horn of Furnadu, from which it is now separated by a channel 6 feet deep. The sea sometimes sweeps across near the end of the E. horn of the same island, and will sooner or later cut off its head to form a fresh island. *B* and *C* are stony patches rising 2 or 3 feet above the high tide level with spits growing out to the W.; they lie just within the boulder zone of the reef, and are covered with loose, coral fragments. *C* has a single coconut tree about 7 years old, while *B* is quite bare; neither have signs of any former timbering, and this fact, together with their positions, leads me to consider that both probably are of recent formation. *D*—*G* are sandbanks awash, but *H* is a stony tree-covered islet that has formed in the same manner as *B*; it almost completely covers the boulder zone outside itself. Finally, *K* has been separated from the seaward horn of Farukolu, but this whole limb has now been cut, in addition, into three islets by three narrow canals which have formed across it from the outer reef. These are peculiar, in that in the largest the minimum breadth is not more than 20 yards; they average 3—4 feet deep, and have almost straight-cut sides as if chiselled out by man. Their bottoms are formed of bare rock, and have a slight growth of coral, but the reef flat outside them rises to the usual level on seaward reefs, i.e. that of low tide. Lastly, the island between the two limbs of Farukolu no longer exists, nor was I able to trace definitely any junction of the same with Farukolu, though to judge from the general changes found elsewhere on this reef it seems almost certain that it has become joined to its W. horn; much of its inner or east side must have been washed away in any case.

The seaward reef to the S.E. of Furnadu, beyond the boulder-covered beach, is only about 30 yards broad, but towards the middle of the island reaches about twice this breadth. In its inner part it is very rough, but with few loose masses of rock, giving place outside to an absolutely bare reef flat with a well-marked edge which continues evenly against the sea with practically no fissure formation. The whole right up to the edge is scattered with pinnacles, masses of the elevated rock. Many of these are of extraordinary size, and a considerable proportion attain a height of 7—10 feet above the reef flat, about 2—5 feet above the high tide level. Most are undermined somewhat, and the surfaces of all are much worn. They show their composition fairly well, but the force of the sea is too great to allow many upstanding coral colonies to be worn out of the rock. At the south end, on the inner side of Furnadu, at the base of the U a number of similar masses were found, which in their corals clearly showed their origin to be due to a small elevation.

While to the S. of Furnadu almost the whole seaward reef is covered with rock masses, to the N. they become continuously fewer and more scattered. Beyond the island a few are found on the boulder zone and inner part of the reef flat the whole way along to Farukolu, but they gradually decrease in size further N. Opposite the centre of the shoal the E. reef is much broader, and has the regular reef flat characteristic of seaward reefs, the edge however being more regular than is usual. Lastly, off Farukolu the reef is about 60 yards broad, the outer 40 yards of which form an almost bare and typical reef flat, while the inner 20 are covered with rock masses.

The W. reef has outside an only moderately steep slope with a broad area of growing corals, of which 20—30 yards of its inner edge reach the low tide level. Inside this lies the sand flat, which against the land forms the boat channel, but between Farukolu and Furnadu, where the whole reef narrows somewhat, continues as a great sand flat with nowhere more than 3—4 feet of water at low tide. On it sedentary life of all sorts is singularly scanty, the whole being covered with loose sand, which is washed up by the wind into temporary banks. The ordinary sand-living organisms also, such as *Sipunculus*, *Ptychodera*, and *Holothuria maculata*, are curiously rare except within the horns of the main islands.

Ereadu (Pl. XX.) is a crescent-shaped island enclosing a velu or basin with 2½ fathoms of water. Round its outer shore lies a belt of stony land, varying in breadth from 45 yards in the middle of the E. side to 80—90 yards near the points. Outside this to the E. there is no reef flat, the slope commencing from the base of the beach, which is 10 feet high. It is very gradual for about 40 yards out, where the depth is only a fathom or so. N. and S. a flat of about the same breadth at the low tide level is found. A singular point is the complete absence of pinnacles and of any definite masses of coral rock. The whole stony belt is covered with loose corals, but the latter are not rounded off in any way, as if thrown up by the sea. This fact, together with the presence of a definite, high ridge behind the beach, makes it difficult to suppose that the corals can have reached their present position save by elevation. Yet the coral blocks looked singularly fresh, although the inner 20 yards of the stony area were formed mainly of *Porites arenosa* colonies, many 7—8 feet across, a coral which does not grow to any size on the seaward sides of reefs. Near the points the rocky belt stretches across the whole island, and is formed of small fragments, etc., obviously piled up by the waves. The points themselves show distinct outgrowths towards one another, which in time might close in the central basin of the whole reef, turning it into a lake or *kuli*.

The sandy area fringes the velu to the N., S., and E., and its shores are everywhere to some extent washing away. Broad sand flats fringe the beach to the N. and S., but in the centre of the E. side the shore slopes directly into the lagoon, a depth of 2 fathoms being reached within about 20 yards. A reef joins the points of the island, rising generally to the low tide level, but with two channels serving for small boats. It is mainly covered and apparently formed in its upper few fathoms by massive colonies of *Porites* (including *P. arenosa*)

and *Goniastraea*, and towards the inner part of Miladumadulu bank falls off to 20 fathoms in about as many yards.

Ekasdu is fairly accurately represented on the chart and, if it be bisected in a N.N.W. and S.S.E. direction, the seaward half would be found to be formed of coral rock and the lagoon half of sand. The reef N., S. and E. is about 40 yards across, and consists of a bare flat with near its beach an occasional pinnacle of coral rock. To the W. the reef is much broader, varying up to 120 yards, and has all the characters of the W. reef off Furnadu. The land shows little loss or gain, but there are several lines of sandstone on its W. beach; to the S.W. a point is growing out by the piling up of sand. The central pool or *kuli* is as charted, and according to the natives has 9—12 feet of water in its centre; its water is now quite fresh enough to be pleasant to drink. The presence of mangroves against the pool, and of an enormous number of a peculiar species of prawn, *Leander gardineri*[1], in its waters shows that it must have been at one time connected with the sea.

Maungudu resembles Rymagu in having all round the land a reef flat, 20—50 yards broad, and almost completely exposed at low tide. The outer half of this is in most places bare, but the inner is much strewn with large rocks or else consists of a rough coral rock, the whole averaging perhaps 18 inches above the low tide level. Inside this the beach is mainly formed of coral masses, but sand—of which the central, lower part of the island is entirely composed—enters largely into their composition.

Kuda Mandu (Pl. XX.) needs no special description on account of its resemblance to Ereadu. Indeed, the charts are almost interchangeable, the only differences being in this island having its opening to the S.W. and its basin 3½ fathoms deep. The whole shore of its velu except to the S.E. is being washed away. The reef joining the ends of the island is well-formed, and reaches the low tide level. The outer part is very rich in corals, and slopes to only 2 fathoms in about 100 yards. Noticeable on its inner part is a line of elevated rock, 36 yards long and exposed for 4 feet at low water.

Bodu Mandu (Pl. XX.) resembles the last, but its opening lies to the S.E. The island is a thin rocky belt to the N. and E. with a reef about 30 yards across. To the W. it is much broader and all formed of sand; the reef is about 150 yards across in the centre, and has a number of masses of rock, showing that the land once extended right out to its edge. The land to the S. is built up of stones and sand, and is very narrow. The opening is joined by a reef similar to that off the last island, but narrower. Behind it the lagoon shore is protected by mangroves, but near the opening there is some washing away. My visit occurring at low tide, I could not enter the velu, but the natives state that it has a maximum depth of 4 fathoms.

Kalaidu has a stony belt, 30—40 yards across, round its N. and E. sides with a reef flat 40 yards broad, running out into a long point of shallow water to the N.E. The rest of the island is of sand, but there is no reef, the shore sloping gradually to 3 fathoms in 60 yards, after which comes the usual steep. There is little change save in the S.W. point, which is perhaps growing out. Behind the belt of rock is a low, swampy area, about 1½ feet below the high tide level, now covered with coconut trees. The latter, however, are growing in a mud, such as—of all the vegetation of the Maldives—only a mangrove swamp forms, so that probably this part was at one time open to the sea. The former shape of the land could not be traced, largely owing to the sand area having been raised 2 or 3 feet by the agency of the wind.

Bomasdu resembles Kuda Mandu in its shape, outer beach, lines of stone and sand, and washing away on the side of its basin, but the island is not growing at its points and covers

[1] *Vide* "Land Crustaceans," by L. A. Borradaile, vol. I. pt. 1, p. 98 of this same Publication.

only the half of its reef. The reef edge to the S. is 750 yards distant, and has inside a bare sand flat with maximum depth of 1½ fathoms.

Breyfasdu has the usual stony belt and reef round its N., and to some extent round its E. and W. sides. Behind there is a mangrove swamp, and the rest of the island is of sand, showing washing away on almost every side. The reef to the S. is 100 yards broad, and has a buttressed edge covered with nullipores—precisely the same as a purely seaward reef—with a boulder zone, behind which a few pinnacles of the elevated rock occur on the flat.

Henbudu is mainly formed of sand, but its beaches are much strewn with boulders. There is a definite reef flat on all sides except the W., generally at least 40 yards broad, the inner half scattered with loose boulders and with a few pinnacles of rock. Near the N.N.W. point is a small pool of water in the flat, about 1½ fathoms deep, but elsewhere the reef is not to any extent hollowed out. Along the W. side the structure is, so far as I have seen, unique in the Maldives and elsewhere. The beach is formed mainly of boulders, and falls 7 feet in 14 yards to a smooth or boulder-strewn flat of about 8 yards in breadth, and averaging nearly 1 foot above the low tide level. This slopes in about 25 yards to 1 fathom or so, but then a number of dead rock masses arise in a line parallel to the beach up to or a little above the low tide limit. Beyond this the slope, which is bare of all organic growth, continues, tailing off finally in a steep about 18 yards further out. The outer line of rocks continues at either end into the outer edge of the reef flat, where the latter exists, suggesting that it shows the former extension of the reef round the whole island. This is of course quite possible, but, if so, it is the only definite case of solution that I have seen within the Miladumadulu bank.

Kendikolu is one of the largest islands of the Maldives, but only a small part of it is capable of cultivation. It has a rocky belt against the sea with a similar reef to that off Ereadu, both together averaging about 150 yards in breadth. This passes somewhat abruptly to the N. and S. into the sandy part of the W. side, which has no reef but a sandy growing beach with isolated coral patches off the same, sloping gradually to 18 or 20 fathoms in about 200 yards. Down the centre of the island separating the two areas is a series of three lakes, surrounded with mangroves, and separated from one another only by banks covered with the same trees, not improbably in the first place artificially erected by the natives of the island. These lakes are filled with fresh water, but do not attain a greater depth than 5 feet; they average in breadth together with their mangroves about 500 yards. Two saltwater fish, that commonly live in backwaters and ascend rivers, *Chanos salmoneus* and *Gobius criniger*[1], were found in them.

Tolandu, **Malandu** and **Landu** all have stony belts, slightly washing away, with the usual narrow reefs to the N. and E. and sandy shores to the S. and W. The first two islands have broader reefs to the W. with pinnacles of rock, but that off this end of Landu is no broader than that off its N. or E. shore. A mangrove swamp is said to occur within each of these islands, but I myself only saw the one in Landu. In this island there is a narrow freshwater lake to the N.E., surrounded by mangroves and separated by a rocky belt of 60 yards in breadth from the sea. The area of the swamp is now much restricted, but numerous mangrove swamp plants occur throughout the centre of the island, and the surface of the ground is riddled with the large holes of *Cardiosoma carnifex*, an essentially mangrove swamp crab. The animals of the kuli include three fish, *Gerres maldivensis*, *Mugil coeruleomaculatus*, and *Barbus vittatus*[1], and a prawn, *Leander debilis*.

Mafaro west reef (Fig. 100) is nowhere exposed at low tide, and has a very bare appearance, being largely sand-covered, with here and there a patch of low corals. Inside this is a mud flat

[1] *Vide* "On the Fishes from the Maldive Islands," by C. Tate Regan, vol. I. pt. 3, p. 279 of this Publication.

which surrounds the whole velu, being only broken opposite the N.E. passage. The maximum depth found in the velu was 4 fathoms, the central part of the basin being a uniform flat at about 3½ fathoms. The N.E. passage towards its lagoon end has a maximum depth of 2½ fathoms, but to seaward it shallows still further, and between the outer points of the reef—which are 130 yards distant—only reaches a depth of 1½—2 fathoms. Throughout its whole length the channel is studded with growing coral shoals, almost reaching the surface, with towards its lagoon end sandy areas between, but towards the open sea with almost its whole bottom covered with sedentary organic life.

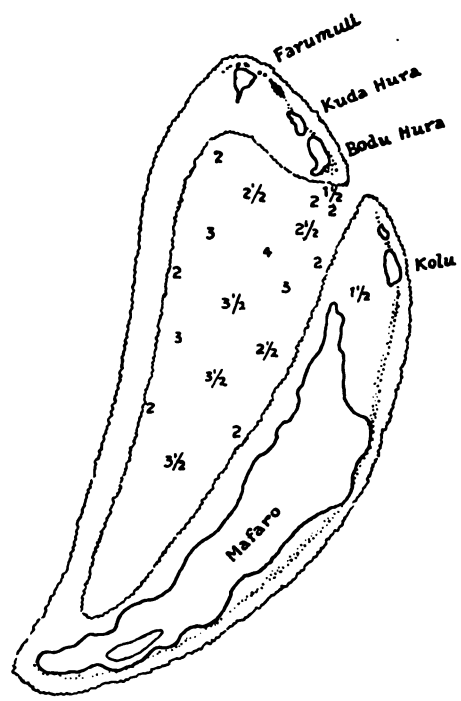


Fig. 100. Mafaro Island and Reef.

Round the E. side of **Mafaro** the reef, where no land exists, consists of the usual reef flat, boulder zone—either of the two with pinnacles of the elevated rock—and sand flat. Wherever rocky land is found there is a reef, quite similar to that off Ereadu. The northern three islands are all of rock and appear at one time to have been connected, being joined along the reef by a succession of pinnacles of the raised rock; Farumuli too has traces of a mangrove swamp in its centre. All the islets at the present time are slightly washing away to seaward, but sending out points of loose stony materials towards the lagoon, against which Bodu Hura has a small accumulation of sand. Kolu is separated from the main island by 6—9 feet of water, and consists of rock to the E. and sand, very rapidly washing away, to the W. The main island has behind the last a sandy spit strewn with fallen bushes to the E., but possibly slightly growing out to the N.W. S. of this the island has on the N. and S. thirds of its E. side a narrow rocky belt, between which the sea has cut into the land, and is forming a bay. At the S. end is a mangrove swamp. The lagoon side of the island shows no definite change but, if anything, is extending outwards by the piling up of sand.

Manadu has a narrow stony belt to the E. with a smoother and more marked reef flat than the northern islands of the bank. To the N.E. it has three rocky islets (Fig. 101) that have been cut off by the sea from the main island. With the exception of a rocky seaward belt the latter is formed of sand, which is growing out especially to the N.N.W. and S.S.W. To the N. and S. the reef is 100 yards distant, but to the W. there is no reef, only a series of coral patches to 2 or 3 fathoms, 40 yards from the beach, and then a gradual slope to 18 fathoms in an additional 70 yards. An interesting point in traversing the island from W. to E. is a series of sand dunes, almost ridges running N. and S., and varying up to 21 feet in height. These possibly show waves or periods in the growth of the island by the accumulation of sand to the W. They could not on account of the vegetation have been heaped up save in the immediate proximity of the sea.

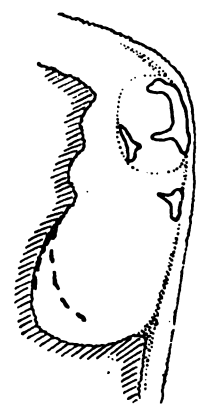


Fig. 101. Manadu, N.E. of the Island showing erosion.

Edufaro (Fig. 102) has on the W. side a very distinct surface reef with a single boat channel to the N., enclosing a lagoon of 2—3 fathoms. It has two main islands, which have the usual rocky belt and narrow reef to seaward. The sand has for the most part been

removed from the lagoon side of the land towards the N. of the bank, while it has somewhat accumulated to the S. In the centre, where the islands approach one another, there is marked washing away of the land and much fallen timber. The N. end of the S. island has been cut off and broken into four separate islands, three on the reef flat mainly formed of rock, and one against the lagoon of sand.

Miladu is a sandy islet with a stony beach of broken corals and of sandstone to the N., S. and E., where there has been considerable loss. There is no definite reef round the land, but a belt of shallow water is found with patches of corals and other organisms arising on a sandy bed. **Magudu** and **Rohi** were not visited but, viewed in passing, appeared to be precisely similar in structure to the last island.

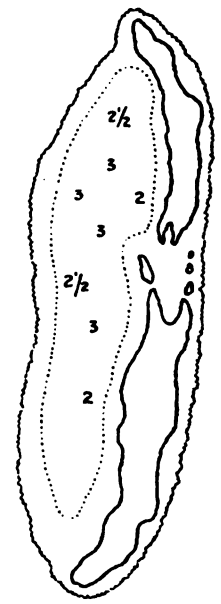


Fig. 102. Edufaro Islands and Reef.

V. Fadifolu (Fig. 103).

Fadifolu ranks in the Maldives as one of the more circumscribed and definite atolls of the group on account of its single line of reef, almost completely encircling save to the S.W., and the open nature of its lagoon, which is free from any large shoals and islands. In respect to the latter the last two islands left, the Innagiri—shown in the chart of 1836—have been completely washed away. Records, however, are still preserved of four other islets on shoals in the centre of the atoll-lagoon, that had gone even before Moresby's chart was made. One of these of peculiar sanctity was stated to have existed on a reef marked on Moresby's chart with soundings of from 10 to 15 fathoms. For an island to have been situated anywhere in this area its condition must have been very different formerly to that of the present day, consisting as it does of a number of very small reef patches, occupying a considerable area, none large enough to support land. In respect to the present actions on all these shoals within the lagoon our observations were not sufficiently numerous to deduce any changes, but by analogy with the more enclosed parts of Mahlos it is clear that they are breaking up into smaller reefs and being removed.

The relatively dead nature of the inner parts of the encircling reefs everywhere against the more enclosed areas of the lagoon of Fadifolu and the changes, more particularly noticed at Inawari, Naifaro and Difuri, leave no doubt but that the lagoon is increasing on all sides at the expense of these reefs. In this connection it is interesting to observe that our dredgings showed the bottom of the lagoon to be quite smooth, with no signs of growing organisms, that might in time form definite shoals, and covered with a thin coating of sand, in most places on a hard (? rock) bottom.

A close comparison of the present day conditions of the passages into the atoll with those of the chart was impossible though eminently desirable. On each side of many of these channels towards their seaward ends distinct points were found, extending out from their bounding reefs, which might by growing together ultimately obliterate at least many of them. Instances were found, too, of separate reefs of the rim that have become fused. Our impression certainly was that everywhere the rim reefs were growing together to form a single enclosing band, though of course there are physical reasons against its being likely that this consummation can ever be completely effected.

In connection with the last question I more particularly investigated the passage next north of Naifaro, which owing to points having grown out from the reefs on either side is narrowest at its extreme seaward end. The passage has, it should be observed, a bend in the centre off the south end of Madewaru island, the foundation reef of which extends relatively further south than marked on the lagoon side. Within a few yards of the reefs on either side of this passage I got depths of 13, 14 and 15 fathoms with a depth in the absolute centre (both in its length and breadth) of the channel of 19 fathoms, which apparently continued without decrease to the floor of the atoll-lagoon. Going outwards, however, the bottom rises to a line with 12—13 fathoms along the seaward edge of the

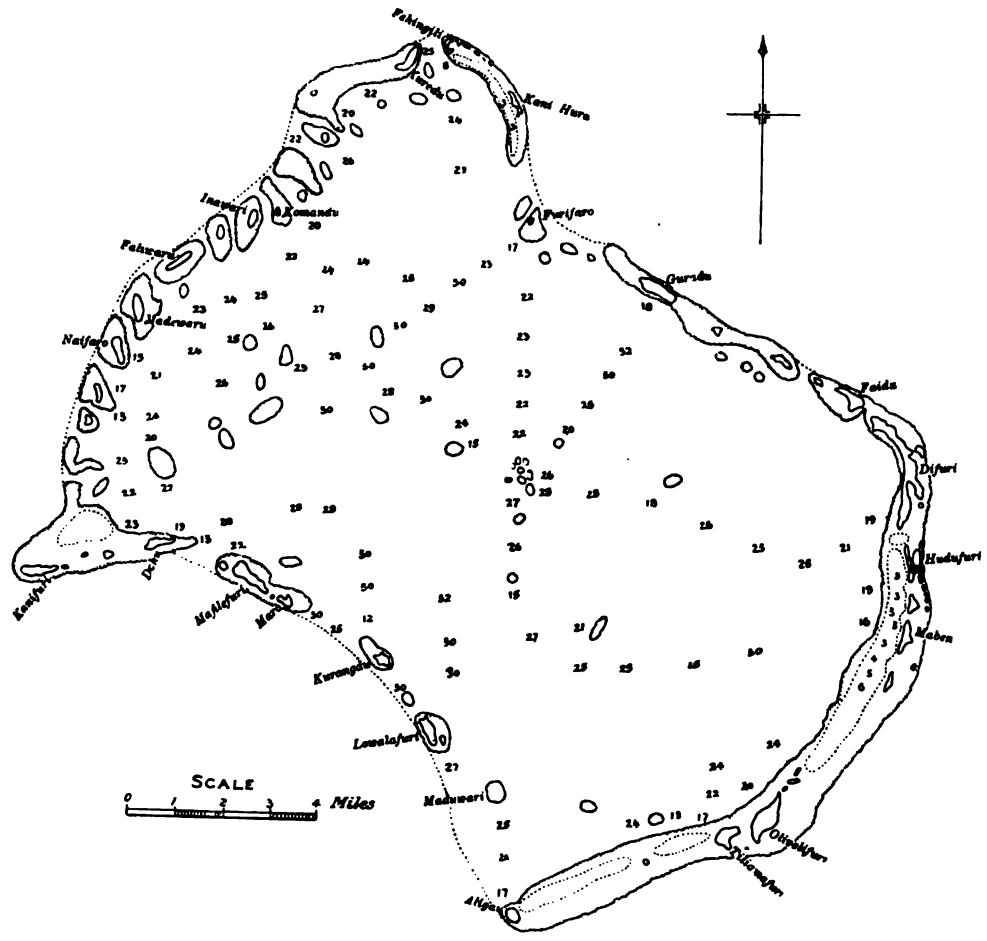


FIG. 103. Fadifolu Atoll, considerably altered from the Admiralty Chart, with which it should be compared.

passage between the points of the reef. In the middle and inner part of the channel, especially near the reefs, a fauna consisting of *Dendrophyllia*, Gorgonians, Alcyonaceans, sponges, etc. was obtained without difficulty, the bottom being relatively smooth. Along the outer ridge on the other hand dredging was difficult on account of the large, heavy coral masses, but a quantity of the material covering the bottom was secured. Among it some of the ordinary reef corals were found growing, but the greater part consisted of dead coral, held together by sponges, Tunicates, Polyzoa and more particularly *Lithothamnion*. Much of

the dead coral from this position was in small masses, as if due to a piling up by the currents, but this appearance, as that of the relative absence of living corals, may have been due to the powerlessness of our dredges to give us a real idea of the nature of such a bottom. On each side of this ridge the reef was in its slope (11 fathoms in 16 yards) less steep and dead than further within the channel, being covered with much *Madrepora* and nullipore growth. There seemed then to be a definite upgrowth along a line across the passage almost against the outer slope of the atoll, a character which I was also able to detect in the next two channels to the south, but which I was almost unable to trace so clearly elsewhere in the whole Maldive Archipelago. It is interesting to observe that in the passage north of Naifaro on Dec. 26th, 1899, no current was found on the surface with a rising tide and wind of force 6 from the north-east, while in six different positions, 8—16 fathoms deep, currents setting seawards were found, varying in force from 1½—3½ miles per hour.

The various changes of land and sea are dealt with below for the islands severally, but it is remarkable that on none of the reefs we visited to the west did we find any rocky land, any trace indeed of elevated rock. To the east on the contrary there still exist at least the remains of an almost continuous line from nearly the north to the south point of the atoll. The sandy land of the lagoon side was probably piled up from the lagoon behind this line of rock, and there are now places, where the same process continues. If any rock ever existed on the west rim, it is impossible to believe that no trace of it would have been left. At the same time sand areas without rock could not have been formed under the sea except at some considerable depth. It hence follows that the sandy islets of the west side must have been formed by sand washed up from the lagoon, and it is necessary to suppose that the reefs of the west rim were less perfect before elevation than those of the east rim, and still some distance below the surface of the water.

Kani Hura, Fehingili, and their reef to the N.E. of the atoll (Fig. 104) are quite irreconcileable at the present day with the old chart, so much so indeed that it is extremely difficult to see what changes have really taken place. The N. end of Fehingili is of stone, and appears to be growing out, while the S. side is washing away, the island marked x having been cut off from the same. South of Fehingili along its reef is a series of no less than seven new islets, which are apparently of stone outside and of sand within, their outer edges resting on the boulder zone, beyond which is a well-defined reef flat. Kani Hura has a fringe of rock to the N.E., which side shows generally a loss. The rest of the beach is of sand growing out, slightly to the W., but more extensively in a spit to the S.W. The seaward side of the S. end of the island shows a line of beach sandstone along the reef. Beyond this there is a flat, a kind of boat channel, but not hollowed out, and with some patches of loose stones. Further out again is a line of the elevated coral rock, extending along the reef for some distance to the S., but not elsewhere found on its surface. These masses of rock in this position lie on the inner part of the reef flat, but in other positions there is a well-defined boulder zone, the rocks of which are represented in this situation by the loose stones between the reef flat and the beach of the island. The reef, examined as a whole, shows from this line of elevated rock that a great island must have at one time extended to the S., while probably all the land to the N. is of quite recent formation with the possible exception of a patch near the northern passage.

The reef to seaward of Kani Hura, and indeed everywhere that I saw to the E. of Fadifolu, has the typical outer slope, reef flat and, where no land is present, boulder zone. To the W. of Kani Hura there is a sand flat sloping to a velu, which extends nearly along the whole length of

the reef with a depth of two or three fathoms, smooth sandy bottom with little or no sedentary life. An irregular line of reef with a series of surface patches, through which a passage may anywhere be found, forms a barrier for this pool against the atoll-lagoon. Along its whole length the character of this reef varies considerably, its surface being in some places covered with knolls of coral, and in others almost bare; everywhere a characteristic, almost perpendicular, fall to the lagoon was found. Of the two shoals represented to the W. of Kani Hura I could see no signs, though all those marked in the chart near the N. passage were quite distinct.

Furifaro is the southernmost of two reefs—the two reefs to the N. shown in the chart have become completely fused—separated from one another by a quite narrow channel, almost a canal. The island itself is washing away to the W., but growing out to the N. and E. It presents a peculiar appearance, being covered with low shrubs to the E. rising to immense *losa* trees (*Morinda citraefolia*) to the W., where the shore ends in a small cliff. To the N. there is a steep, sandy shore, which falls practically to the bottom of the N. channel. E. the reef is the same as off Kani Hura, but W. it differs in being covered with living coral colonies, presenting here quite the appearance of a growing reef. The reefs in the channel to the S. of Furifaro are flat-topped and reach the low tide level.

On the western side of the atoll **Kuredu** is washing away to the S., but, if anything, being extended by the piling up of stone to the N. and along by the side of the passage, where its enclosing reef is very narrow. The S. island on this same reef, which the people remember to have been covered with coco-palms, is now a mere sand bank with three small trees.

Komandu is of sand with a large reef, to which are now united the reef to the N. and the small patch to the S.E., but about half of the latter does not now exist, so that the passage is fairly clear. The island is washing away N.E. and S.W., but growing S.E.; to the S.W. there are three lines of beach rock running out upon the reef, which at its edge consists of a series of separately rising coral patches.

Inawari is a sandy island increasing both N. and S., but very decidedly washing away to the E., where I found that a former graveyard, at least thirty yards across, had been very largely removed, the whole shore being strewn with human skulls and various other bones. Off this part the natives of the island have erected breakwaters, which three times in the last forty years have had to be renewed. Outside at the low tide level there is a dead flat of coral rock—a reef flat—which ends precipitously against the lagoon. The natives state that the reef is narrower on this side than when they were young, and that both it and the land are being washed away at the same rate. The reef to the N. appears to be growing out so as to close in the passages on either side of our shoal, and there does not seem to be any separate reef as that marked off the S. end. A comparison in this neighbourhood with the chart is impossible, but it is clear that the island was originally placed too far to the W. on its reef. The presence of a clear, broad passage—we anchored in it after twice tacking—on the E. side is not to be reconciled with the chart, unless one supposes that the W. reef has really been washed back, a supposition which its dead condition shows clearly to have been quite possible.

Madewaru is all of sand, washing away rapidly to the E. and less quickly to the W., while apparently growing out at its N. and S. points. It is, however, always very difficult to decide about the changes of sea-swept points, where as in this case practically the whole island is covered with such bushes as *Scaevola koenigii*, *Tournefortia argentea* and *Pemphis acidula* without any high trees.

Naifaro is, like the last island, of sand, and shows the same changes. Its reef on the E. side is all dead, and nowhere more than 120 yards broad. At its edge is a breakwater erected by its people, outside which a depth of 12—15 fathoms was found in 3—4 yards, the slope being almost perpendicular and with no animal life. All the islands to the S. of Naifaro as far as those on the Kanifuri

reef differ in no respects from the northern ones, being formed of sand and washing away towards the lagoon, and perhaps against the sea, while more or less growing out at their ends. Their reefs to seaward differ though from those of the E. side of the atoll in having no definite boulder zones, only two zones being found, the sand flat (or boat channel) and the reef flat. The former differs in no respect from that occurring elsewhere, save that coral life is especially abundant upon its surface, but the latter is rougher, though less fissured at its edge, with more growing coral colonies and other sedentary organisms than is usually found on the seaward reefs of the Maldives. The E. sides of all are singularly barren, with a peculiar dead appearance and much algal growth.

The condition of **the great S.E. reef** of the atoll is best shown by the chart (Fig. 104). The reef is continuous from Faidu to Aligau, and, indeed, there are no considerable breaks on the E. side except those on either side of Furifaro. N. of Faidu is a small stone heap on the point of the reef against a very narrow passage. This is joined to **Faidu** itself by a line of rock, outside which the sea breaks at only a distance of about 60 yards. Round Faidu island the rock forms a belt against the sea, 7 feet above the high tide level, passing outside into a reef flat, studded on its inner half with pinnacles of the raised rock. The rock is everywhere washing away, as shown by the undermined and fallen trees and pinnacles, but to the S.W. of the island is a considerable, probably growing, area of sand. Between Faidu and Difuri is a bight of water from the lagoon, 12 fathoms or so deep at its inner end; this appeared to run across the greater part of the reef, but the sea was breaking in a continuous line across its outer end on both the days I spent in this neighbourhood, so that any investigation was impossible.

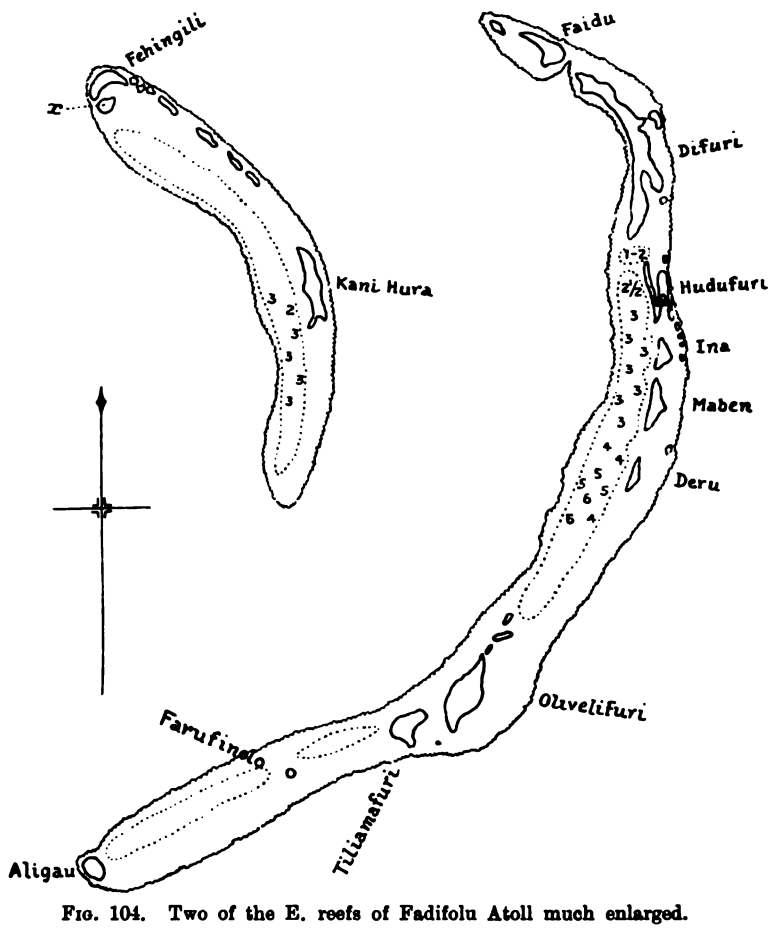


Fig. 104. Two of the E. reefs of Fadifolu Atoll much enlarged. Compare with Fig. 103.

The clump of islands of which **Difuri** is the northernmost forms more or less a double series, although some islands by extending into both lines join them. The outer line forms a series of nine small wooded islands, joined to one another by a series of rocks on the reef. These islets are all built of rock alone, and their outer shores lie about 60 yards behind the seaward edge of the reef. The second, or inner, series consists of three much larger islands, which are all composed of sand. These

islands do not reach to within a considerable distance of the seaward edge of the reef, on which side they vary greatly in shape. To the W., however, their shores form a line 500—600 yards behind the lagoon edge of their reef. Belonging to both the series are the islands Hudufuri and Difuri. The southernmost of these, Hudufuri, has a belt of rock right on the outer side of the line of rocky islands, joined by a narrow isthmus—formed by two deep bays to the N. and S. of the island—to a stretch of sandy land as decidedly belonging to the inner line. Difuri is less regularly divided, but a bay to the S. with for the most part rock outside and sand within indicates the two lines.

As to the changes going on there is to the E. of the rocky belt a marked washing away, which, continuing for some distance round the ends of the islands, has formed the deep bays in Hudufuri and Difuri[1]. There is also some slight washing away to the E. of the islands of the sandy line. To the W. of these same islands there is practically no change at all, but the ends of all these islands are growing out along the reef towards one another. Whether the islands themselves will ever meet is uncertain. They are at present separated by channels of 4—6 feet of water with very strong currents, a depth so unusual for such a position that it appears probable that the dividing channels increase in depth with their restriction in breadth, the two processes going on until equilibrium is established. The above, however, is not quite true for Difuri, which, while perhaps a little growing at its ends, shows a distinct washing away along its whole lagoon side.

From the N. end of Hudufuri to the Olivelifuri clump of islands a velu extends along the W. side of the reef. It is separated by a sand flat of about 90 yards in breadth from the inner line of islands, but opposite the channels between them this flat broadens considerably. Its depth varies from 3 fathoms to the N. to 6 fathoms a little south of Deru. As to its character it is quite open, and has a soft, sandy bottom. Life, both free-living and sedentary, is in it very scarce, the latter being only represented by a few coral knolls on the W. side and some small coral colonies opposite the passages between the islands. To the N., almost between the islands of Difuri and Hudufuri, is a separate small pool of 1½ fathoms.

The lagoon reef is a flat about 50 yards broad—narrower to the S.—part of which seems to be awash at low spring tides. The whole way along it appears to be so even that a man could wade upon it at low tide from Difuri to Olivelifuri, and probably from the latter again to Aligau. Along the W. of Difuri it extends for about the half of the length of that island, thence further N. gradually merging into an area, where there is no true reef, but merely a number of isolated perpendicularly-walled reef patches with sandy ground—the slope of the Difuri shore—between. Against the lagoon the reef has no edge, but passes into an area covered with large, massive *Madrepora* and *Porites arenosa*. This again opposite the islands falls precipitously to the atoll lagoon, but in the open part to the N. of the Olivelifuri set of islands we found an area with 5—10 fathoms of water, covered with loose, dead coral masses, the dredges and swabs practically failing to secure any fixed life at all. To investigate this small bank would have required a residence for a considerably longer time in the atoll than we had to spare. We found no area elsewhere which could be in any way compared with it, and I am inclined to think that it is a formation entirely due to local causes. The currents of the N.E. monsoon would naturally sweep along the reef by the islands and across in the open space, clearing off any coral masses from the W. reef and depositing them inside. Further, the condition would be almost that to the W. of the long main island of Funafuti, where there is in the centre an extensive and increasing deposition of sand[2].

Off **Olivelifuri** I was unable to localize any fixed point of the reef to the S.E., the contour appearing quite rounded. The island is of sand alone, and no part approaches within 200 yards of the reef edge. All sides of the land except perhaps a sand spit to the S. show washing away. This

[1] These are inhabited by immense numbers of stinging rays, a fish which we saw nowhere else in the Maldive Group.

[2] *Vide* "The Coral Reefs of Funafuti, Rotuma, etc.," *Proc. Camb. Phil. Soc.* vol. IX. p. 435, 1898.

is best seen on the N. side, where two islets have been cut off within the last sixty years. Beyond these again arises a third little sandy islet, the only remains of the one shown in this position in the chart. To the S. a rocky mass stands on the reef much nearer its seaward edge, half-way to Tiliamafuri. The latter island is all sand, with one possibly stony point to the S., and is slightly washing away along its lagoon side.

Between Tiliamafuri and the tiny sandy islet of Farufinolo there is said to be a shallow velu, and beyond the latter there is certainly one to Aligau, which is mainly formed of rock, the reef closely fringing the land both N. and S. The three reef patches marked in the lagoon in this vicinity were all clearly defined, the one marked Maduwari alone being noticeably larger than shown.

VI. North Male.

My investigations in this atoll were confined to cursory examinations of the south-west reefs on our voyage to Goifurfehendu atoll and of the east rim reefs on our return to Male island from Fadifolu, and to a nearly two months' residence at Hulule and Male, when some of the islands and shoals in the vicinity were visited. Mr Forster Cooper also made an eight days' sounding and dredging cruise throughout the centre of the atoll.

I have little to chronicle about the North Male bank, which seemed to be in a very stable condition. All the rim reefs are well-defined on their seaward faces, even those to the south-west of the bank. Most of them, indeed all that are not merely small reef patches perhaps with land, are definite faro, including the reef of Immufuri and those to the north-east of Asdu. In the larger faro of the east side the depths of the velu are very uniform, varying between 5½ and 8 fathoms. All on the east side have well-formed reefs against the atoll-lagoon, except that opposite Mirufenfuri on the Difuri reef there was a break of about 1½ miles with from 3 to 6 fathoms of water. Most of these velu of the east rim are bounded to the west by sand-flats, which decrease in breadth as their whole faro become of more perfect formation. They are not found in this position in the Difuri faro, nor in that next south of Helengeli, the velu of these last being separated from the atoll lagoon by mere rims of growing coral. The latter, indeed, bound all to the west, and consist of coral colonies, not consolidated together in any way, which at about 3—4 fathoms pass into a precipitous or almost perpendicular fall to about 20 fathoms, or to within about 5 fathoms of the general level of the lagoon bottom in the vicinity, the surface of this slope being almost completely bare of sedentary life. The characters of the reefs of the west rim of North Male are not so well-marked, but most are definite faro, some of which are very imperfect in their eastern or lagoon reefs.

The reefs within the North Male lagoon of more than half a mile in diameter, that are marked in the chart, appeared to be all definite faro, though some, such as that on which the island of Barosse is situated, with shallow velu—only perhaps 1 or 2 fathoms deep. Our dredging, the lines of which must have covered about 75 miles of the bottom, failed to find any definite coral patches or reefs growing up, the surface of the lagoon floor being almost flat between the different shoals and covered with coarse or fine sand. Inequalities existed, it is true, but these did not seem more favourable for coral life than the deeper parts. Some of the reefs appeared to have enlarged to a considerable extent, while of others we could find no trace of their former existence. Many showed a marked trend along the direction of the currents, which would cross the atoll. This was particularly the case near

Barosse, but it was quite impossible to reconcile the existing reefs in this neighbourhood with those drawn in the chart. Some seemed to have become joined together, while others had bodily shifted their positions—or fresh ones of large size had grown up—and yet of still more no trace could be found.

On the whole the changes in North Male lagoon were so great, and beyond our experiences in other parts of the Archipelago, that I could only conclude that they were either due to so-called "corrections" of the original chart, or to difficulties that we know to have existed in making the first survey, and which would necessarily have been very great nearest Male, the Sultan's island. Owing to this, with the insufficient means at my command, it did not seem to me worth while examining the area, as otherwise I had intended. I may, however, remark that in my opinion, in which my companion concurs, this was the only part of the whole Maldive group that we saw, where there could have been any such inaccuracy in the original survey. Indeed, the south half of North Male atoll for this reason, and also in the interests of trade, all vessels entering at Male island, demands to be resurveyed in a proper manner.

With regard to the land five fresh sand banks were seen by Mr Forster Cooper between Male and Hembadu to the south-west of the atoll, all on inner reefs, while two islands of the east rim were found to have been washed away. All the islands within the lagoon and most of those of the rim are of sand. Where within the lagoon the island covers the most of its bank, such as Wagrenfaro, Hefuri and the two Bundusi, there is no living reef, and the island is washing away, whereas, if there is a large reef or faro, loss is more than counterbalanced by gain. None of these inner islands show any signs of elevated rock, and it is probable that all owe their existence solely to the piling up of sand from the atoll lagoon. The same seems to be true of most or all of the islands on the western rim, but on many of the east rim reefs elevated rock is found behind which the sand, forming the larger areas of the several islands, was probably by the same means heaped up. This was particularly the case off Hulule, where between the boulder zone of the reef and the island a series of masses of the elevated rock was found on the sand-flat. Their position here about 30 yards behind the boulder zone shows the former extension of the land, and also points to a considerable outgrowth of the reef to seaward, sufficient at the least to have formed the reef-flat since the original elevation took place.

VII. South Male, Felidu and Mulaku.

I have very little to record about these banks. They show remarkably little change in the contours of their reefs since the original survey was made. Some islands have formed, while others have washed away. As on other atolls the rule on the east rim is a washing away at the seaward ends of the islands, bounding, or off, which elevated rock is commonly found. There is a tendency for the formation of fresh islands—mostly at present mere sand-banks—along the encircling reefs, wherever they extend in a more or less east and west direction. The most remarkable example of this is the Hurasfinolo reef in South Male, to the north of which five such banks have formed. On the whole there is curiously little land to the north and south of these atolls as compared with others in the group, and this is still more especially the case on the west side, particularly when considered in conjunction with the more perfect atolls to the south. Such land as there is on the latter side is mostly

formed of sand; a few rocky banks, it is true, do occur, but most of these are obviously piled up by the waves, and there are extremely few, if indeed any, pinnacles, undoubtedly belonging to the elevated rock. Fresh islands and sand-banks are not infrequent on the west side, and probably all the land in this position has been formed by the heaping up of sand. Further, the relatively small reef patches which form the west rim, as compared with the east, are remarkable, everything in conjunction pointing to a much less perfect condition of the west side as compared to the east, when the original elevation, that formed so much of the land of the Maldive banks, took place.

My companion, Mr Forster Cooper, who investigated the lagoons of these atolls by soundings and dredgings, reported singularly little change in them. The depth nowhere had decreased, but an increase was rather indicated, though on account of the difficulty of accurate fixation it was impossible to afford definite proof of the same. Most of the larger interior reefs are faro, and even smaller ones of 150—200 yards in diameter have the centre rather lower. None definitely showed growth. All have precipitous slopes with an area of decaying coral masses around them.

Only ten passages into the different lagoons were examined, in three of which distinct shoaling was found. In seven an apparent constriction seemed to be taking place by the outgrowth towards one another of points from the neighbouring reefs. Upgrowths of new shoals near the inner ends of two passages occurred, a most unusual feature at the present day. No areas, covered with living corals, such as might form shoals, were met with in the interior of the banks, but isolated massive colonies of *Goniopora* and *Alveopora* were frequently dredged, and some parts were much covered with the living and dead coralla of the solitary *Diaseris*. *Dendrophyllia*, which of all the corals was most frequently dredged in the living state, seemed for the most part to be confined to passages and current-swept areas.

VIII. North and South Nilandu (Fig. 105).

I cannot do more than call attention to a few points in these two atolls, which in their topography are intermediate between the more open banks and the more perfect rings of the Maldives. The characters of both banks are so admirably shown in the charts that it is only necessary for me to refer to the shoals within their lagoons. These in different situations show in their characters every grade between the similarly-situated reefs of Miladumadulu and those in the most enclosed parts of Suvadiva or North Mahlos, from reefs that are indubitably growing outwards to others that are as certainly being removed by solution and other agencies. All the shoals on our course seemed to be correctly placed in both atolls, but in the south of the northern atoll we found in addition six uncharted shoals and three others in which growth was particularly strongly marked. Most of the shoals within the encircling reefs of the atolls were represented in the chart as presenting flat tops without land. All over 200 yards in breadth that we examined—twelve in number—in addition had velu, definite little lagoons (Fig. 105), whereas a central pool was only charted in a single one. In the southern atoll the same prevalence of velu was noticed, and indeed their presence in all the larger shoals of either atoll appears to be the rule. Beyond this a considerable enlargement was found in all the charted velu that we passed, whether in the lagoon or rim reefs.

The above facts appear to me to be of considerable significance as bearing on the formation of lagoons in general, treated of more particularly in my Chapter (VI.) on North Mahlosmadulu bank. It seems to me to be nearly impossible to believe that there is any error on my side, or on that of the original cartographers, by which the above changes can be explained. The charts were in the first place so carefully made, and pools of deep water, wherever present in the lagoon reefs, so carefully charted on other banks that North and South Nilandu —and probably also Ari—give the strongest support to the view that atolls can be and are commonly formed by the spreading outwards of surface reefs and the solution of their central parts. I believe that owing to the shallow depths of their foundation flats, their protected situations and other peculiar conditions the lagoon reefs of these two Nilandu banks show, even in the odd 64 years since the charts were drawn, the change from a flat reef to a perfect atoll. In their entirety, too, these lagoon reefs give a complete series from the smallest reef, a single coral head—perhaps only a single coral colony—to an atoll a mile or two in diameter.

A point, everywhere observed in the Nilandu atolls, was the decreased breadth of the lagoon reefs, which separate the velu of the rim from the lagoons of the atolls. All the rim velu had increased in size, and, while much of this was undoubtedly due to growth in length, yet more would seem to have been caused by increase on their lagoon sides. The lagoon reef of any velu in the rim of either atoll is generally perfect, but it is only a thin line, 40—60 yards across, covered over the greater part of its breadth with living corals. It differs among other points from the reefs to seaward in never having a boulder zone and in not being backed behind—and so separated from the velu—by a sand flat of a quarter or half a mile in breadth, such flat, if present at all, being

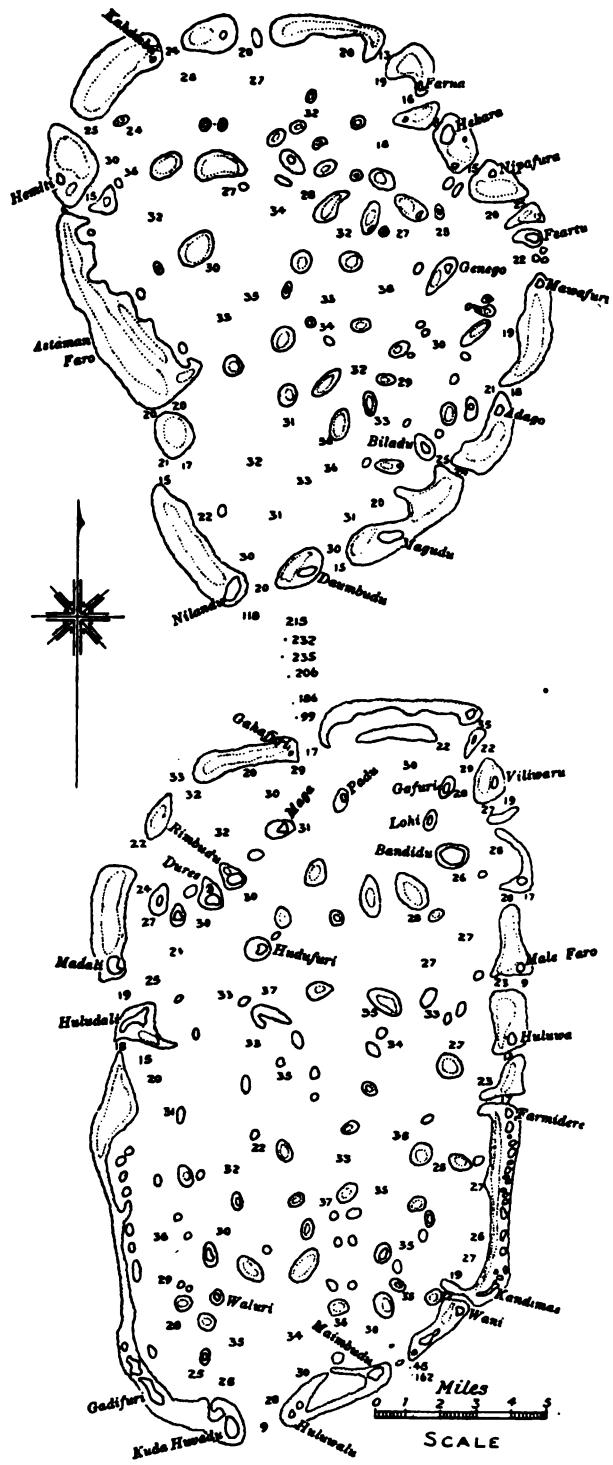


FIG. 105. North and South Nilandu Atolls (*considerably altered from the Admiralty Charts*).

seldom more than 30 yards across. In the lagoon shoals also a similar narrow breadth of the reefs round the velu, where no land of any sort exists, was also observed. The solution where the reef is protected, eats up almost to the growing coral layer, and, if any accident befall these animals so that they die, it is easy to perceive how that the water of the velu and of the atoll-lagoon will quickly eat a passage through the reef, and join one another. In this connection the south-west reef of South Nilandu is most noticeable, as it appears to have had a long linear velu, which has now become joined to the lagoon of the atoll, leaving, nevertheless, a series of isolated reef masses, parts of the original great breakwater.

The land of both atolls is nearly all built up of sand, and there are many fresh banks of the same formed on reefs in the lagoons, though it is doubtful whether many—or indeed any—of these will ever form islands, covered with timber. The changes in the land are mainly local, depending on the passages, etc. in the immediate vicinity of each separate island. No signs of pinnacles of elevated rock were observed, and it is possible that the elevation, such as it is in the Maldive region, had no part in the formation of the land that exists in either of these atolls[1].

Within the lagoons no changes in depths were found. The bottom in most places is of hard rock or sand, and in South Nilandu its fauna was richer than on any other bank in the group. Indeed six dredgings in this atoll yielded as great a variety of animals as any consecutive eighteen elsewhere, and the number of specimens of some of the species of Crustacea, Echinoderma and Mollusca was extraordinary. Of the passages into the lagoons only those we traversed in going into and out of each atoll were examined. That of Maimbudu was found to have a shoal of 7 fathoms in its centre within a few yards of the 40 fathom line, the steep of the reef commencing from the shallowest water of the channel. In Mawafuri passage three shoals, almost reaching the surface, were found.

IX. Kolumadulu and Haddumati[2] (Figs. 106 and 107).

These atolls resemble one another closely in that they have single and relatively perfect encircling reefs, enclosing large lagoons with 40—45 fathoms of water. The lagoon shoals of each are comparatively small, although fairly numerous, with the regular, almost perpendicular cliffs usually found around them. None have land, unless situated close to large passages into the atoll lagoons, and none are faro. Both have for the greater part of their circumference single rather narrow reefs, without pools of water in the centre. Both are exposed on the east and also on the west to the full force of the sea, and on the other sides are afforded little or no protection by the neighbouring banks. Lastly the land in each is mainly situated to the south and east, in some positions consisting of lines of islands almost joining one another, while to the north and west the reefs are very bare.

The islands are for the most part formed of sand alone, and, as a general rule, are to seaward bounded by a well-defined sand flat, boulder zone, and reef flat. A few, however, send out heads as far as the boulder zone, and these are generally washing away at their ends. Behind, their necks are usually being cut through so as to separate the rocky outer

[1] That this is really the case is, however, distinctly unlikely. Our time was too short to enable us to stop and examine the individual islands, and our attention was mainly taken up with the almost universal faro formation of the shoals.

[2] My knowledge of these atolls is confined to two hurried visits in the s.s. *Ileafaee* in going to and from Suvadiva. In addition Mr Forster Cooper spent 10 days in Kolumadulu and 8 in Haddumati, dredging and sounding the deeper waters of their lagoons.

ends from the larger sandy inner areas, and in many places isolated islets, or rock masses, so formed are found in or just behind the boulder zone. Most islands are separated from the atoll-lagoons by broad flats, and in but few are definite changes of any sort indicated on this side. The sandy islands commonly show a slight washing away on their seaward faces with often, where many islands are present, a growth of spits towards one another, or, if an island be isolated, along the reef. In some places, too, sand-banks have formed on the reefs, and here and there an island seems to have been completely removed. The most marked change was seen at Fahala in Kolumadulu, to which has become joined the small island to the north. The south end has on the contrary been completely washed away, and in its place

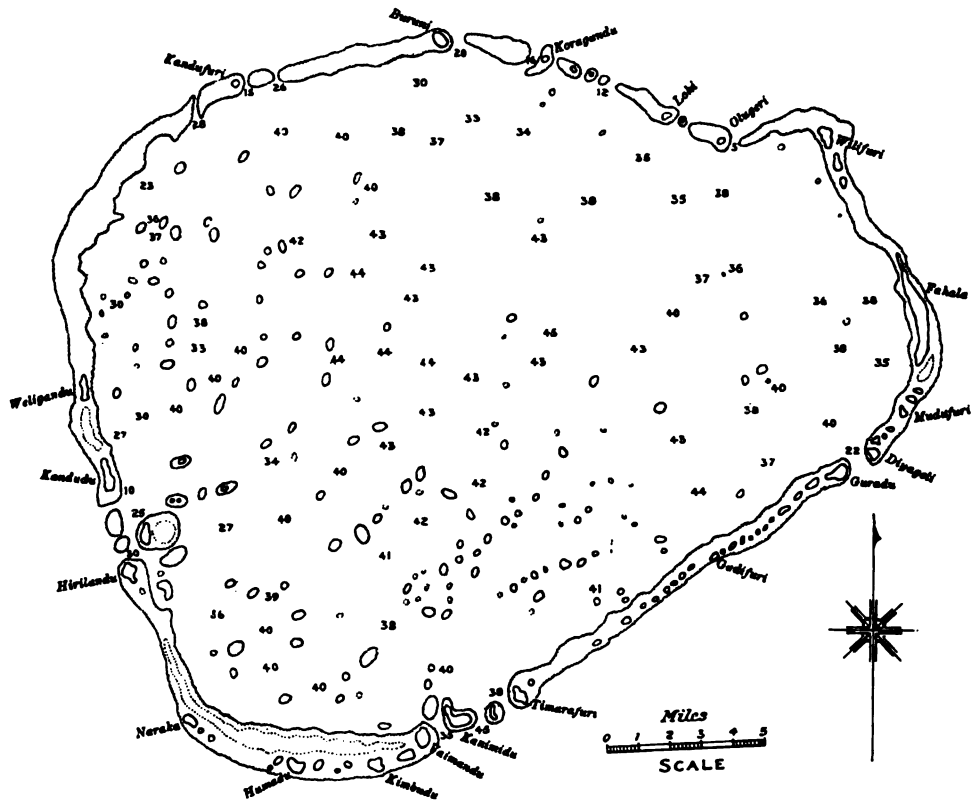


FIG. 106. Kolumadulu Atoll (*a little altered from the Admiralty Chart*).

is a double velu in the centre of the reef, the largest and deepest part to the E. Further south the next seven islands mostly have to the east rocky points, which are being washed away, while the sandy parts behind are growing out along the reef towards one another, so that the south four have nearly fused. Isdu in Haddumati sends out a point to the boulder zone north-east and another north-west, both of which are probably outgrowths, while the north end of Dambidu has been cut off to form a fresh islet. The latter has also taken place at Funadu, but the second island north of Ghang has been washed away.

Within the lagoons of both atolls a mixture of sand and mud is found, covering the bottoms, on which a few Mollusca and Crustacea alone live. In some places there is a covering of low green algae, and in others horny or siliceous sponges. Mr Forster Cooper nowhere recorded a determinate change in depth, nor did I find any in a close-set line of

soundings between Guradu and Buruni in Kolumadulu, nor in isolated ones from north to south in Haddumati. The vast majority of the shoals that we fixed were found to be as marked in the chart. Mr Cooper, however, observed that several, which were represented as reaching the surface, only existed as mounds well below the low tide level. In passing through Kolumadulu, too, I observed that a few presented in the sunlight a dark, blackish appearance—a contrast to the vivid brightness of a growing reef. Two of these near the north of the line between Guradu and Buruni I crossed, finding both completely submerged and apparently quite dead, being covered by fine mud with no living corals.

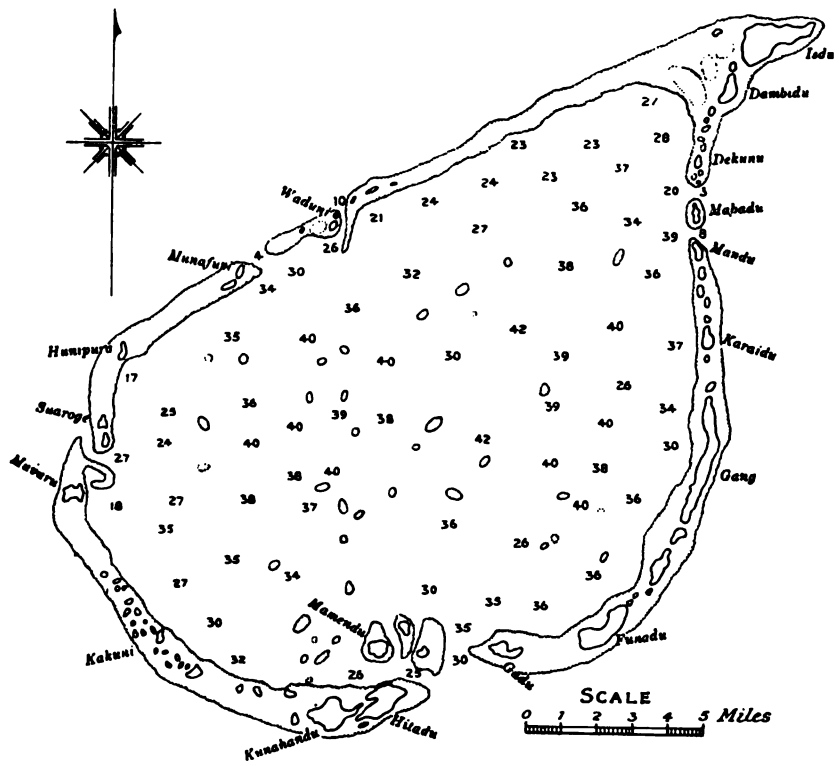


FIG. 107. Haddumati Atoll (*slightly altered from the Admiralty Chart*).

As far as the passages were concerned, I only examined four, and found changes in all. This was remarkable and probably due to the fact that all four were among the largest in either atoll. In Kolumadulu the Buruni reef had grown out somewhat to the north-east, its south-east horn seeming in addition to have been somewhat cut away, and the Guradu passage had narrowed near its seaward end by reefs growing out into it from either side. In Haddumati the Munafuri passage has as least depth in its centre 4 fathoms (seven soundings), but it differs from the Guradu one in having very distinct outgrowing horns towards its lagoon end. The Gadu channel is constricted by an outgrowth of the Gadu reef to the west, and by that to the south of both the reefs between Gadu and Mamendu, the Hitadu reef showing no changes.

X. Suvadiva Atoll (Plate XXI.).

Suvadiva is such an immense atoll that it was scarcely possible to see sufficient of it, even in five days, to venture on any conclusions as to its formation and origin. It is really an isolated bank by itself, separated by broad channels from the other parts of the group, in which Prof. Agassiz found 1130 fathoms towards Haddumati and 1292 and 1048 fathoms towards Fua Mulaku and Addu[1]. A vast contrast in size to the latter and to the northern banks of the line, Suvadiva, among the whole area of the Maldive and Laccadive groups, is only comparable in a small degree to Haddumati, between which and Kolumadulu Prof. Agassiz found 1118 fathoms. A better comparison would be with the Great Chagos Bank, which might well represent an incipient stage of such an atoll as Suvadiva.

On account of its great size, deep foundations, almost perfect rim, and large, open, and relatively deep lagoon, it is necessary on almost any theory of the formation of atolls that has been propounded, to assume for Suvadiva a greater age, a longer period of time since its foundations were laid, than is necessary for any other bank of the Maldives and Laccadives. With increased perfection of shape, too, the difficulty of deducing the stages by which the whole was produced, increases very greatly. Recognising that there is much which can only be understood by the analogy of other banks, I here merely draw attention to the changes and conditions which seem of general applicability to the whole atoll, before passing to a somewhat more detailed account of the parts I visited, than I have thought it necessary to give in respect to the other parts of the Maldives.

The land exhibits the usual changes found elsewhere, in some parts showing loss and in others gain. The reefs everywhere to seaward have the typical outer slope, reef-flat and boulder zone. The latter is formed entirely of loose masses of rock, the skeletons of corals and other reef organisms, fragments off the reef outside, and sometimes blocks of a consolidated rock, that now lies above the low tide level. Some of the islands have to seaward a belt of rock and there are also found isolated masses and pinnacles of the same on the seaward reefs. Much of this rock shows its origin to be due to elevation, but no definite pinnacles are found in the boulder zone, so that it is probable that the whole, or a considerable part, of the breadth of the latter and all that of the reef flat have grown out since the elevation took place. The raised rock is being eroded away, but loss at the present time is being balanced by gain, though it is certain that the land once formed a much more continuous, if considerably narrower line, upon the encircling reefs. Along the lagoon sides of the islands there is in places loss, but it is not general, the reefs being usually broad and in some parts seeming to be growing out. The latter, however, is only the case in the more open parts of the atoll, the opposite conditions prevailing to the S.W. Some of the reefs round islands within the lagoon are growing out in places, but the islands themselves with very few exceptions are gradually but surely being washed away.

Points of the reefs, extending out into the lagoon by the mouths of passages, might conceivably grow round in time to meet one another, and by fusing form velu in the rim. I could, however, find no sign of their doing so, or having done so, while on the contrary such velu as there are in the rim, are gradually being put into connection with the atoll lagoon. Some of the shallower passages are undoubtedly being closed up, both by the growths of organisms on their bottoms and sides and also by the pushing out of points against the

[1] "An Expedition to the Maldives," *Amer. Jour. Sci.*, ser. iv. vol. xiii. p. 301 (1902).

sea from their bounding reefs. The deeper passages, although they literally teem with animals, seem neither to have shoaled nor to have been at all constricted.

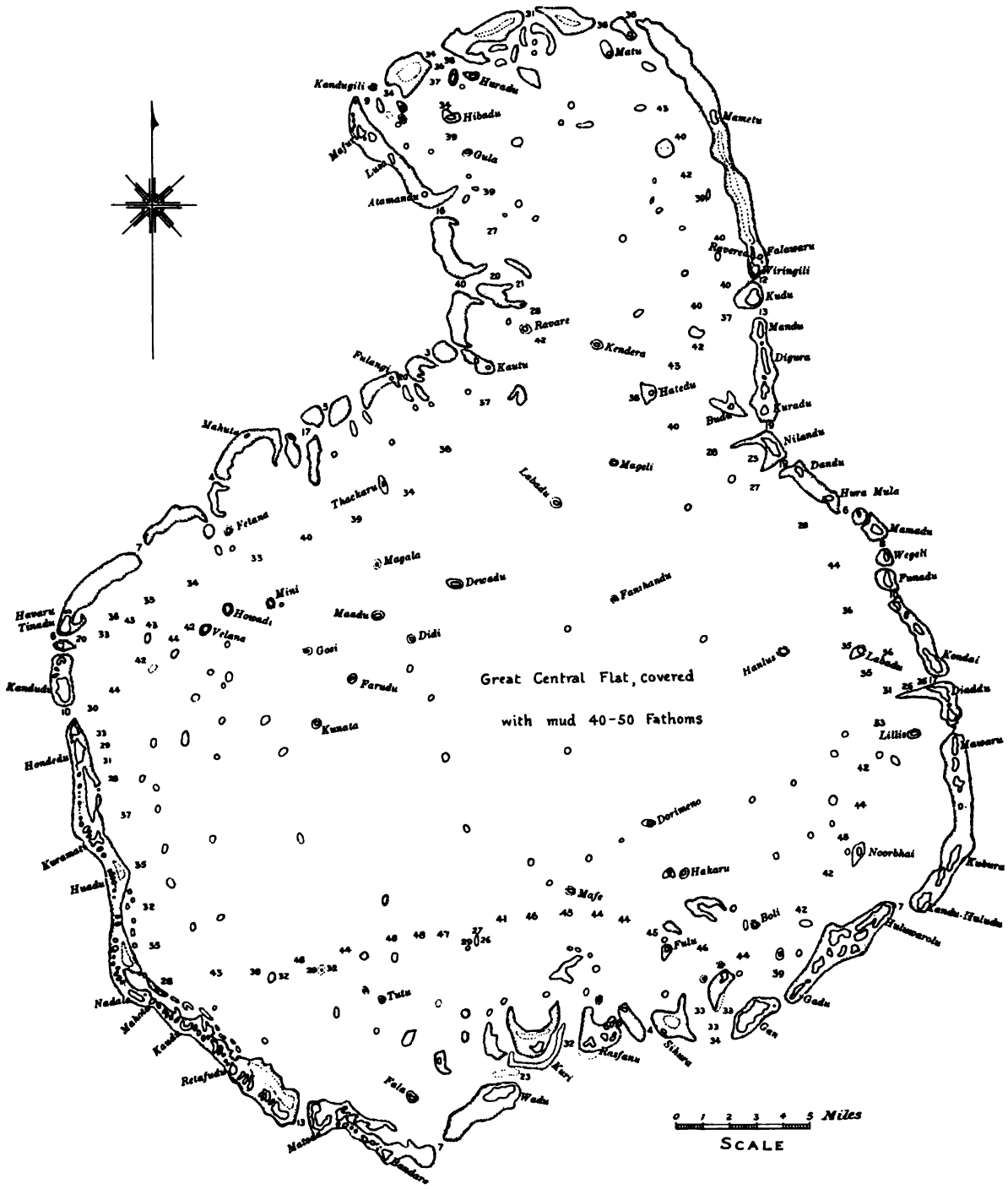
The lagoon is remarkably uniform in depth, and its bottom except near passages is everywhere coated with mud, to which I have already referred in Appendix A, Sec. II. "On the Formation of Lagoons." The shoals to the south and west of the lagoon, and to the east with a few exceptions, viz. those which have been referred to with growing points, have precipitous slopes from about 4 to 30 fathoms with very narrow rough areas around, strewn with dead masses from the flats above. Among these sedentary reef organisms do not grow, while every stone is riddled with boring animals, and very quickly destroyed. It is impossible for the larvae of sedentary animals to become affixed on a muddy bottom, and there is no piling up of sand anywhere, so that what change there is in the lagoon is likely to be one of loss rather than gain, an action possibly shown by an increase in depth, found especially towards the south part of the atoll.

Matu and the island opposite to it on the other side of the passage are both of coarse sand, and covered with tall coconut trees. There has been a little loss to the E., but there is no marked change. I could not find the shoal shown to the E. of Matu, but all others and the depths as far as Wiringili are as represented. The island to the N. of **Mametu** has disappeared, and to the S. of that island the reef has a narrow velu, extending along the whole of its length. To the E. of it in the centre are two rocky masses, standing on the sand-flat behind the boulder zone of the reef, their summits a foot or two exposed even at high tide.

Wiringili is mainly formed of sand and occupies the S. end of the reef. Its lagoon-reef is rather low, no part being exposed at low tide, and the shore, 200 yards behind its edge, has a few fallen coconut trees but no signs of extensive loss. To the S. the island is fringed with an area of coral rock, the beach lying on the inner edge of the boulder zone. The latter and the reef-flat merge round the S. of the island into the reef of the W. side, while the island sends out on it to the S.W. a stone-covered spit. On the east side the rock has been pierced, and the beach washed back from the boulder zone. The channel between is now a bare, smooth flat, covered with low green algae, but four lines of the beach rock show stages in the former washing away. The boulder zone appears to be entirely a recent formation. The two sandy islets of **Raverea** are now joined, and the single island formed is sending out a sand-spit to join one that has grown out from Wiringili. **Falawaru** lies just inside the boulder zone and is formed mainly, if not entirely, of coral rock. Its former connection to Wiringili is shown by a mass of rock halfway between it and the rocky outer end of that island. A few rocks to the N. indicate a considerable former extension of Falawaru along the reef towards Mametu, rock masses showing at the least a series of islets.

The slope from Wiringili reef to the lagoon is very gradual in its greater depths. An edge is clearly defined at about 1 fathom, soundings giving 20 yards from the same 11 *f.*, 30 yds. 12 *f.*, 40 yds. 14 *f.*, 70 yds. 19 *f.*, 90 yds. 23 *f.*, and 100 yds. 28 *f.* At 11 *f.* the bottom had growing on it between large, bare, sandy areas, a few small spreading colonies of *Montipora* and *Madrepora*. The reef edge is covered with coral growth, but the colonies as at greater depths are not of large size. There is plenty of variety but no luxuriance, and the quantity of weed present is extraordinary for such an area.

The channel separating Wiringili from Kudu has only 13 fathoms instead of the 15 marked, the soundings across from Wiringili at even distances giving 13, 13, 13, 13, 13, 13, 13, 12, 12, and 11 fathoms. **Kudu** is all sand except for a rocky point to the E., 20 yards behind the boulder zone. Opposite the middle of the island a point runs out from the reef into the lagoon



SUVADIVA ATOLL.

(Soundings in the lagoon by the Expedition.)

To face p. 411.

for a distance of about 1 mile, the greater part a sand-flat. The channel to Mandu is considerably broader than that to the N. of the Kudu reef, which seemed correctly charted.

Of the lagoon islands **Kendera** is sandy with low shrubs, and **Mageli** and **Labadu** sandy with tall coconuts or other trees. **Hatedu** shoal is much enlarged to the W., and appeared to enclose a small shallow velu; the island, which is of sand with low bushes and a few coconut trees, is washing away on the W. side. The **Budu** reef has grown W.N.W. and E.S.E., a shoal in the latter position having become joined up to it. The passage to the S. of **Kuradu** appeared narrower than in the chart, and we could find no shoal as therein shown.

Nilandu is a sandy island, at present changing very little, situated about 250 yards behind the seaward edge of its reef, on which the boulder zone is, as usual, clearly defined. The seaward shore has much rock, and a few bushes are undermined; lines of the beach rock show that the land once extended at least 120 yards further E. on its sand-flat. The passages, both N. and S., are much reduced in size, the latter by an outgrowth of Nilandu reef. Two horns from the reef, too, have extended out considerably into the lagoon at right angles to the general contour of the rim, and there is a velu with 5—6 fathoms on the S.W. side of the island. Of this there is no trace in the chart, the positions of the soundings on which most decidedly point to its non-existence when the survey was made. The lagoon reef is ill-defined, and has in most places 1—2 fathoms of water with a wide opening to the S., only an odd coral mass here and there reaching the surface; off it the slope is gradual, with bare patches of sand. The velu itself has little coral growth, but there is a fairly marked line of *Goniastraea* and *Porites* colonies against the woody sand-flat of the island.

Most of the islands on to Kondai, our next halting-place, are eroding on their lagoon shores but there are no marked changes in either land or reefs. **Dandu** reef is as shown, but the shoal off the same is situated further to the N.; the island is of sand with rock to the E., and has fused with the next island. We could see no trace of the southern of the two passages between **Mamadu** and **Hura Mula,** and the N. one had broken water right across its centre, indicating an upgrowth; the S. reef of the latter passage too has sent out a very distinct point to the N. The three channels between Mamadu and the Kondai reef were all clear, but the waves occasionally broke across the central one. All the islands had tall coconuts, but the four islands N. of Kondai on the same reef had been reduced to three by the fusion of the two southern.

Kondai is a sand island with a little beach rock to the S., above which is found a cliff of 3 feet and a few fallen shrubs. All loss is on the S. and W. sides, the island being protected by its broad reef to seaward. Due E. starting from the broad sandy beach of the island is a sand-flat, 250 yards across. The first 60 yards of this is covered with sand and weed. The area from 60 to 120 yards from the beach is almost a solid flat of dead *Heliopora*, just covered at low tide; a few colonies, however, were found to be still living towards the outside, where the zone merges into a rougher area continuing out to 210 yards. This has about 1½ feet of water, and is a flat with much dead and rotting coral, in addition to low living colonies of *Porites arenosa*, *P. palmata* and *Pocillopora suffruticosa*, *Madrepora* only commencing towards its outer side; weed is scarce but there is much sponge-growth and many Holothurians. The bottom now, 210—250 yards, slopes up to the boulder zone; living colonies of coral become scarce and weed commences, but there are many large, decaying masses of *Porites arenosa*. The masses of the boulder zone are small, and lie loose on a solid, smooth rock-flat, the inner part of the next area; on the whole the zone is ill-defined, and is broken at about every 70 yards by channels, through which the sea rushes on to the sand-flat. Beyond this again lies the reef-flat, which is much pitted for 20 yards out and almost bare. In the next 30 yards to the reef edge colonies of *Madrepora*, *Prionastraea*, *Montipora*, *Leptoria*, *Astraea*, *Orbicella* and *Goniastraea* were identified. Fissures run in for 20 yards, but they are about

40 yards apart, and always have sloping—not overhanging—sides. At the edge, where there is a small precipice of 2 fathoms, only nullipores were found. The reef outside slopes gradually, the bottom for about 60 yards being quite visible and covered with living corals.

The enormous quantity of *Heliopora* is very remarkable, quite a large area of the sand-flat being covered by it, and without parallel on any reef that I have seen, in the Maldives or elsewhere[1]. Doubtless it is due to the denser skeletons of these Alcyonarians resisting the decay brought about by organisms better than the Madreporaria, the dead corals of which were all much rotted on the same area. The variation of the character of the reef edge compared with more northern atolls is noticeable, particularly in the fissures having sloping, not overhanging, edges.

The seaward reef merges round the S. end of Kondai into the lagoon reef, being about 120 yards distant at the S. point. The lagoon reef has the characters previously described off Wiringili, but its edge is very irregular, and much of the bottom off the same is covered with sand.

Hanlus, Labadu and **Lillis** islands are all sandy and covered with low bushes. The only change was seen in an outgrowth of the reef of Labadu to the W.S.W. The islands of **Diaddu** reef are likewise all sandy with spits along their reef. Diaddu island and reef both show an outgrowth towards the lagoon. **Mawaru** and the island to its S. are joined, as indeed nearly are the next pair on its reef. The reef of the sandy **Noorbhai** island has extended out to the S. and there has appeared a small shoal to the E. The reef from **Huluwarolu** to Gadu has a double set of islands, the eastern formed partially of rock, but the western composed entirely of sand. The latter are extending out towards one another, and one has already become fused up to Huluwarolu. The two islands next N. of Gadu have very extensive formations of beach sandstone on their seaward sides.

The seaward or E. reef of **Gadu** is similar to that off Kondai, but there is no *Heliopora* zone and less dead coral; the boulder zone also is more conspicuous. The land behind shows a little erosion, and there are lines of beach rock on the sand-flat. The island is only built up of stone to the S., and this part consists principally of pebbles, which have become consolidated together; inland may be traced the lines of three former beaches, showing how the land has been extending outwards on its reef. The beach against the passage almost runs on to the boulder zone, which has towards its inner part a definite line of elevated coral masses, now much undermined. The inner flat in this part, wherever it exists, is peculiar in that it consists of bare rock with no sand. The reef also has right round its edge a crest absolutely similar to that at Rotuma[2], an equal development not being found by us elsewhere in the group. The boulder zone further extends right round to the lagoon side, where the edge of the reef almost reaches the surface, thence falling almost perpendicularly to the floor of the lagoon.

It is difficult off Gadu to trace the line of the original elevation, but the land probably never extended out to the E. as far as the present boulder zone. In this position there is a line of coral pinnacles about 90 yards behind the reef edge, 40—50 yards within the boulder zone. This continues as far as the eye can see to the N., and, if it be taken even as the inner end of the original raised reef, would show an outward growth for the present reef of at the least 70 yards since the elevation took place.

The waves during our visit to Gadu were occasionally breaking right along the whole distance to Gan, the passage seeming much narrower than shown on the chart. **Gan** itself is quite similar to Gadu; its reef has grown out to the N.E., and there is a stone heap in this position on the boulder zone. The island shows marked loss on the S.W. side, but N.W. the lagoon-reef is only

[1] It compares only with the raised *Heliopora* reef, described at Funafuti by Professor Sollas in *Nature*, vol. LV. p. 376, and referred to by me in *Proc. Camb. Phil. Soc.* vol. IX. p. 422 (1898).

[2] "The Coral Reefs of Funafuti, Rotuma, etc.," *Proc. Camb. Phil. Soc.* vol. IX. p. 442 (1898).

50 yards broad. The lagoon islets in the neighbourhood are all sand heaps covered with bushes, their shores giving signs of more or less considerable loss.

From Gadu we went almost due W. to Nadale, putting down 25 soundings on the way. All these showed an increased depth as compared with the chart, varying from 1 to 6 fathoms. They contrast with those of the E. side, where the depths were all about the same as recorded. Indeed, there appeared to have been a real difference, an actual average increase of about 2 fathoms in depth along our line. The bottom was everywhere coated with mud, except in the immediate proximity of shoals. The latter along our course were all located, and appeared to be smaller, but no accurate observations or comparisons were possible. The lagoon islands all showed washing away, but the process evidently is not very rapid. With regard to the southern encircling reefs there is a marked tendency to velu formation, but most of the enclosed pools are stated by the natives to have formed one or more communications with the lagoon of the atoll.

The islands immediately to the S. of Nadale show varying degrees of washing away on their lagoon sides. To seaward all run out into points, formed of coral rock, which are separated by some breadth of sandy boat channel from a continuous boulder zone. All have towards one another points of mixed sand and stone, apparently growing out to join the whole line together. **Mahota** thus is almost a rhombus in shape, the two acute-angled points to seaward and lagoonward, and the two other angles towards Nadale and the S. Erosion is taking place on **Nadale** both towards the sea and the lagoon, but the former is very slight, the beach being formed of coral rock. The latter forms a belt 100 yards broad, but does not seem to have ever extended out as far as the boulder zone, the reef-flat having been formed by the outgrowth of the reef edge. On the lagoon side the water has broken through the sand into a kuli, which formerly seems to have occupied the centre of the island. At its entrance is a small sand islet with three coconut trees.

On its lagoon side Nadale has a sand-flat, noticeable for its enormous quantities of sand-feeding Holothurians and Polychaets. It is about 400 yards broad, and ends abruptly with large clumps of *Madrepora* against a velu full of coral patches, 8—12 fathoms deep. These masses increase in size towards the lagoon, and are characterised by their perpendicular, or overhanging, sides, built up of such massive genera as *Goniastraea* and *Porites*. Some are so large that their centres are bare, or even slightly hollowed out, and quite dead. The E. reef is well-defined and likewise arises perpendicularly from the velu, but towards the atoll lagoon the bottom is visible for 150 yards, covered with great areas of *Madrepora* and *Lobophytum*. The velu appears to stretch S. as far as **Kaudu,** sending small bays out towards the sea between the different islands, and communicating freely with the lagoon. To the N. the velu continues for about 2 miles, but then its enclosing reef gives place to a series of isolated shoals, a small velu only appearing again to the N. of **Huadu.** This change is evidently due to the breaking up of the reef, the original line being clearly shown by the regularity of the line of shoals.

The islands from Nadale to **Hondedu** have all sandy beaches on their lagoon sides, exhibiting little or no signs of erosion. Their seaward ends have rocky shores, and reach generally to the boulder zone, which is well-marked; change is all in the direction of loss rather than gain. Between the islands on, or inside, the boulder zone is a series of coral masses awash, which indicates that the land formerly extended in an unbroken line from Hondedu to at least **Kuramati.** The latter island is interesting from its dumb-bell shape, two heads against the lagoon and sea, joined by a narrow bar, either side of which is strewn with timber. This is peculiarly interesting, as showing how the removal of the land may take place from the middle of a reef outwards. It bears also on the meaning of the presence of a double line of islands on the encircling reef, as found further N. by Hondedu, and on the E. side between Gadu and Huluwarolu. Sandstone masses lie quite on the lagoon side, indeed almost on the edge, of the reef by Kuramati, Hondedu, and the other islands to the N. It is accordingly probable that land once covered the whole of the lagoon reef in this

vicinity. A further change between Kuramati and Hondedu is seen in the fusion together of all the velu in the reef to form a single large pool. An entrance of about a mile in breadth has opened, however, into the lagoon, considerably broken by coral patches, the remains of an originally-continuous reef against the lagoon.

Havaru-Tinadu can best be seen in the accompanying map (Fig. 108). As it differs so materially from the shape shown in the chart, it is almost certain that there have been great changes. It would seem that the sea has eaten through the outer line of rock and cut into the sand, making a deep bay to the W. The loss is shown in the N.E. angle of this bay in layers of beach sandstone sloping to the W., stretching out from the shore upon the sand-flat. The action of the wind is well seen in a belt of sand, having been blown up for 6–7 feet above high tide level at the bottom of the bay, while the height of the island eastwards is only 2–2½ feet. This ridge averages about 45 yards broad, and passes round the bay into the rocky points. The latter on the beach show a solid coral rock covered with stones.

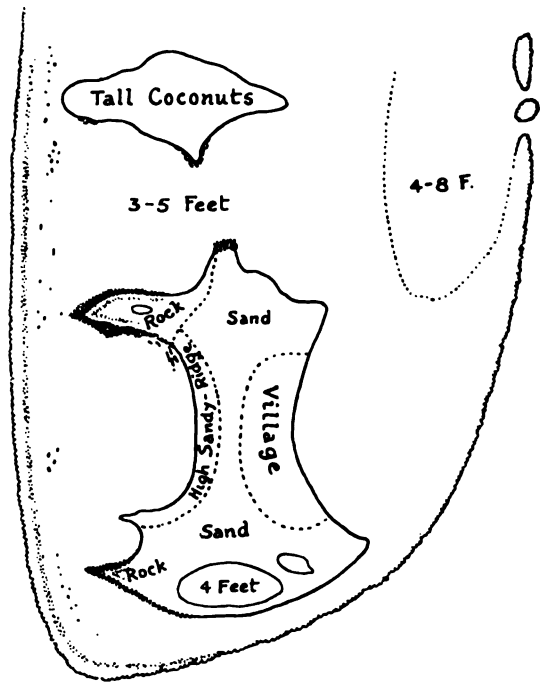


Fig. 108. Havaru-Tinadu (S.) and Mahuta (N.) Islands (*from a sketch map by the author and Capt. Molony*).

The W. bay is remarkable, in that the sand-flat below is covered all over with weed, and near the points strewn with rock masses. The beach is broad, and shows little sign of erosion, or of any other action at present. The sandstone, however, forms a sure indication of its former position, and shows clearly that the action is one tending to cut the island in half. There should be though, if the loss is one of quite recent date, a line of rock masses joining the two W. points within the boulder zone, but only a few small ones exist. On the lagoon side a shallow bay appears to have formed, but whether this is due to washing away, or not, I cannot say. There is no trace at the present time of loss, but rather if anything a washing up of sand on and around the S.E. point[1]. Indeed it is only at the seaward points and around the ends of the island that there is at present any marked loss going on, but even here the action is in most places inconsiderable.

Mahuta and Havaru-Tinadu would once seem to have been separated from one another in the same way as the latter is now being cut in half. Their former connection is shown by a series of sandstone masses—sloping towards the lagoon—extending out from the N. point of Havaru-Tinadu into the channel between, towards a similar point from Mahuta. The W. end of Mahuta is of rock, and a series of coral pinnacles on the sand-flat behind the boulder zone attests the former connection of the islands across their dividing channel in this position.

The lagoon-flat to the S.E. of Havaru-Tinadu is remarkable for the weediness just behind its edge, which is clothed with corals of massive facies; it slopes gradually to the lagoon. Across the two passages to the S. the waves were breaking, making any examination impossible.

[1] One of Moresby's marks—probably of his original triangulation of the atoll—still exists behind this point. It is 120 yards from the lagoon shore at the S. of the bay, and consists of a square metal bar let into the ground, the end at the present time projecting for about 2½ feet.

Our impression was that they were closing up by lateral as well as bottom growth, while the lagoon in the immediate vicinity is deepening, our anchorage, where 17 fathoms were marked, being 20 *f.* The former presence of a velu opposite Mahuta, now opening into the lagoon, is interesting.

None of the lagoon islands in this vicinity nor to the W. are inhabited, and all are stated by the natives to be washing away. **Gula** and **Hibadu** to the N. have much dead and fallen timber. An unnamed island, marked in lat. 0° 37′ N., has completely disappeared, save for a few rocks on the centre of its shoal, covered at high tide. Such reefs as there are within the lagoon extend generally in the direction of the currents, and mostly have precipitous slopes. No marked growth in any was noticed except near the large W. passage in lat. 0° 45′ N. On the contrary Hibadu and Gula had practically no reefs opposite those shores where fallen timber lay, showing that loss of land and reef was taking place almost simultaneously. The large shoal opposite a passage in lat. 0° 41′ N. appeared also to have broken up into five smaller reef patches.

XI. Addu Atoll (Fig. 109).

The most important changes in this atoll have already been dealt with in Appendix A,

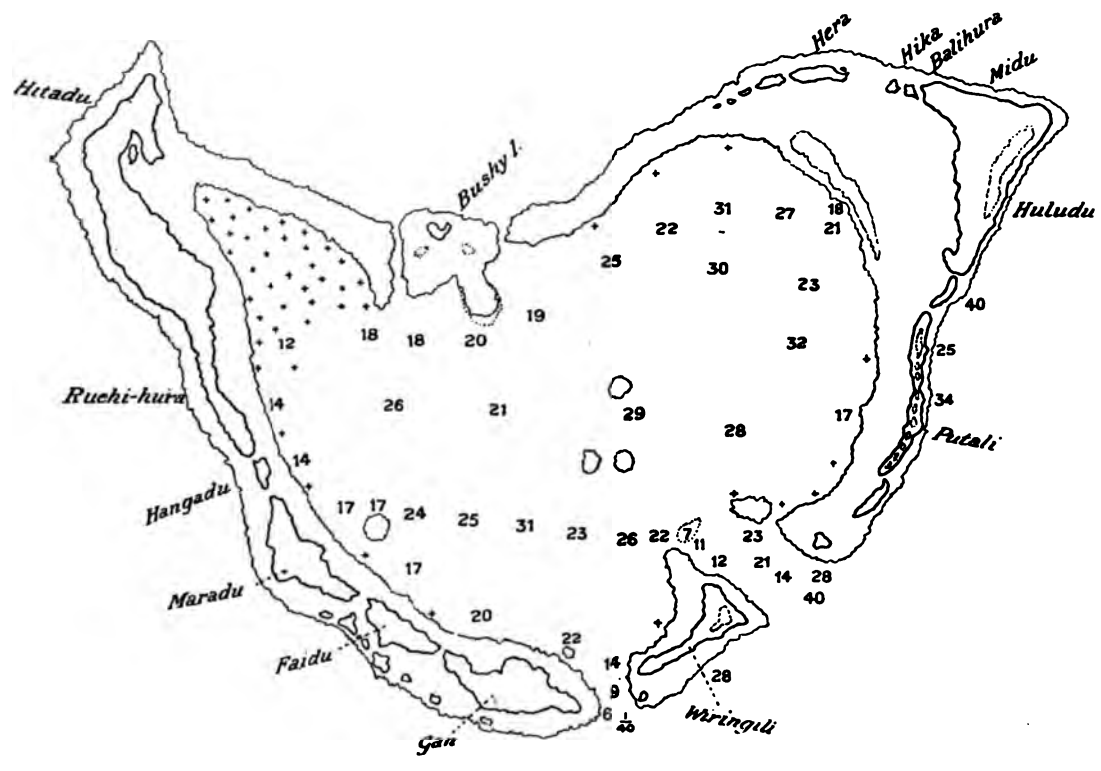


Fig. 109. Addu Atoll. The map is based on the Admiralty Chart, altered in accordance with the observations of the Expedition. Mr Forster Cooper's soundings alone are marked. Scale 2 miles to 1 inch. (*For changes compare the Admiralty Chart on* p. 150.)

Section II. "The Formation of Lagoons." The land shows differences at either end of every island, so that the atoll being small, we could get no even approximately fixed points for our

sights, and the positions of fresh land must only be taken in our chart as comparatively correct.

With regard to the islands themselves they do not differ in structure from those in any other part of the group. All lie on the rim reefs, and the rule is that whatever part of each island falls within about 250 yards, or a little less, of the reef edge is of raised coral rock, and that the remainder is of sand. The greatest height of the rock was found in Hera, *i.e.* 6 feet above the high-tide limit, or about 10 feet above the reef-flat. Rain water denudation has probably been greater in this atoll than in any other, so that there is possibly but little difference between the elevation here and in the rest of the group. The sandy areas of the islands only attain a general height of about 3 feet above the high-tide limit. The sand itself shows that they largely owe their origin to the elevation of sand-flats behind the original enclosing reefs. The surface of the ground, however, has generally been further raised by blown sand, so that the level of the original flats can only be traced in pools, pits and wells.

The seaward sides of the islands show less washing away than in any other atoll. The reef-flat is generally well characterised and relatively broad, merging into a rough or boulder-strewn zone at the base of the beach. The force of the waves is broken before they reach the latter, so that it commonly presents a much smoother appearance than usual, the coral rocks and masses being bedded in sand. In places the latter has become indurated with carbonate of lime, so that there is a broad line of rock at the base of the beach from the half to the low-tide limit. Pinnacles and large masses of the coral rock are not common on the beach, and the appearance decidedly points to the land being at the present time almost stationary, so far as loss is concerned.

It may be here observed that the elevated coral rock of Addu atoll resembles that found at Minikoi and elsewhere, but has always a greater percentage of sand. The corals in it show a more open texture, a more luxuriant growth, and hence the whole rock, being more brittle and open, wears away more evenly than elsewhere.

The outer reef of the atoll is noticeable for its marked edge, less fissured and more defined than usual, but the whole covered with growing organisms. The slope off it is relatively smooth and very densely crowded with growing coral. From its appearance there can be no doubt that it is growing upwards and outwards. Yet on the east side the steep seemed to commence at about 160 yards from the edge of the reef, hence considerably nearer than off the oceanic sides of some of the other atolls of the Maldives. It was observed, though, that the outer slope to the commencement of the steep broadens at every point, showing growth especially in such positions. So far as change has taken place in the contour of the atoll since Moresby's survey, there is no evidence, but the chief points to seaward are all more emphasised and prominent at the present day than shown in his chart. To the south of Huludu there is a shallow bay rather than a point, and Midu point seems very distinctly to have grown out to seaward. The growth also of Wiringili reef to the south and east is seen in distinct points.

Hera, etc. The chart in this position shows six small islands immediately off the N.W. point of Midu, whereas we found two small islets close to the point, separated by a gap about 400 yards broad from a clump of five islets further to the W., of which Hera is the largest. These five form a line on the inner part of the reef-flat or boulder zone, which is clearly

marked between Hera and Hika, and again for some distance along the reef to the W. of the former island.

All these islets are formed entirely of coral rock with the exception of Hera, which, in its broadest part, 130 yards, has on its inner side an accumulation of sand washed up from the lagoon. The small island to the N.E. of Hera is covered with coral stones and may be of quite recent formation. The boulder zone is partially formed of masses of rock, torn off the reef outside or washed off the shores of the islands, but is mainly part of an originally continuous land connection of all these islands to Midu.

Off Hika the shore to the N. presents a steep beach, falling 6 feet, the first 4 feet almost a cliff. This is succeeded by a rough slope, 30 yards broad, passing gradually into a reef-flat of the same breadth. There is again an area of about 20 yards outside the last, with a slight slope to the edge of the reef, which is in this position almost devoid of fissures.

Midu and **Huludu.** Approaching the N.E. corner of the atoll, the reef-flat becomes noticeably bare and smooth, and even broadens further up to 120 yards. Nullipores become dominant towards the point, and cover the whole surface at the edge, which is deeply fissured. The beach passes directly into the reef-flat, there being no boulder, or rough, zone. It is formed of loose rocks, bedded in sand, and may in any place have a small formation of beach sandstone.

Round the seaward side of the whole island, except at the extreme S. end, the rock forms a narrow line, its greatest height about 5 feet above the high-water mark. Towards the interior of the atoll the rock merges to the N. and S. of the island into the sandy area, and is to some extent covered by it. In the centre, however, there is a great rush-covered kuli or lake of fresh water, varying up to 250 yards in breadth. This is cut off by the rock from the sea and by a great sand-flat 3—4 feet high from the lagoon, through which it has retained an overflow channel opening into the lagoon in the centre of the W. side of the island. The sand of the bottom of the kuli and below the tidal limits is everywhere largely foraminiferal and of coarse texture, while that of the surface of the land is fine and mainly formed of ground-up coral. The sandy area of the island, therefore, probably owes its origin to the wind having piled up a bank which effectively cut off the lake from the lagoon.

A small horn to the south of Huludu, stretching northwards into the lagoon, is of interest. It has been partially washed up from the channel to the south of the island, and partially formed by the blown-up sand from off the lagoon-flat. It is evidently growing northwards, and appears likely in course of time to cut off another kuli from the sand-flat.

The islands south of Huludu to the S.E. passage number four, but differ from the chart in the second, Putali being by far the largest. All show a line of rock against a broad reef-flat with sandy areas behind. The seaward beach resembles that off the lighthouse of Minikoi, and further the reef in general appearance is the same.

The northernmost island has a small sand cliff with a few fallen bushes against the lagoon, and Putali at its most southerly seaward point has also some fallen shrubs, but elsewhere none of the islands showed any distinct change in progress. From the appearance of the channels though, to the N. and S. of Putali, it seems to me to be probable that the islands are coming together to form one continuous whole. To the S. of this island there are signs of two points growing out, one by the sea and another against the lagoon. Should these fuse with the next island to the S. a kuli would be formed, quite similar to any one of a series of about twelve rounded pools found in the centre of Putali itself. There is nothing, however, in the structure of the land by these kuli to suggest that any one of them has been formed in this way rather than

by a piling-up of sand, such as has formed the kuli of Midu-Huludu. Further their serial nature along the centre of a very narrow island is scarcely consistent with the second view. Lastly, in the centre of Putali the sea has broken its way through the outer line of rock into two of the pools; the damage, however, had been repaired by the natives with large stones.

Wiringili. The two islands marked on the chart have become joined by a sand-bank, the trees on which are still small. The island is stated by the natives to have a small kuli behind its E. point. The seaward reef is much strewn with boulders, which have accumulated in a bank, with three green shrubs at the S. end. The seaward points of the reef are notably shallow for some distance beyond the reef edge.

Bushy islet to the north of the atoll now consists of a single island covered with shrubs and two sand-banks.

The east islands show five in the series instead of four as represented. This is due to the presence of a small island between Maradu and Ruehi-hura, which was probably accidentally joined to the latter in the original survey. The islands are all formed of sand on their lagoon side, which in some places shows an extension, and in others a washing-away. All are slightly lower in the centre but without definite kuli, although mangroves grow in some. All have more or less stony seaward beaches, but the presence of a rocky area depends on the distance of their shores from the reef edge. Off **Hangadu** the reef is about 150 yards broad, and the island has a narrow, rocky line. N. of this the reef narrows, becoming first quite similar to the reef off Hera; and then off **Hitadu** the land extending to the inner edge of the boulder zone. The reef-flat off these parts has no pinnacles or other rocks, being quite smooth; the rocky area in the land is always well-defined. The timber, with which the latter is clothed, rises for some distance back from the beach, suggesting that it is growing outwards by additions from its reefs. At the W. point of Hitadu this is undoubtedly the case, as also along the N. side, but it is less marked to the S. A characteristic feature of Addu, most noticeable here, is the large amount of sand found with the rocks on the beach in places, the whole appearing to be mainly formed by it. On this side of Hitadu, however, we saw no trace of a beach sandstone formation. Off the reef edge the slope is extremely gentle, the sea breaking in a gale over 100 yards outside the reef edge off the W. point of the atoll.

Maradu is separated from Hangadu by a pool of water 2 fathoms deep, although both to the E. and W. their reefs are continuous. This pool is evidently filling up, consequent, I think, on the reef against the lagoon having reached the low-tide level. There are traces here of a former passage into the atoll-lagoon in a less consolidation of both the seaward and lagoon edges of the reef, the latter being still very imperfect and the former having practically no boulder zone. The island of Maradu itself shows growth along its reefs, as do Faidu and Gan. This should ultimately join all these islands together, but the growth may only be temporary. Further N. by Ruehi-hura there were signs of an irruption of the sea across the land, but no definite gap was created.

The reef off Maradu has a high crest, nullipore-covered edge, but relatively small fissures. The reef-flat is about 40 yards broad, and behind this there is a boulder zone about half as broad, with a boat channel, having everywhere at least a breadth of 90 yards to the land. The boulder zone is low, covered by small loose rocks, and is simply the inner part of the reef-flat. It has here no connection with any elevation of the atoll. Further in, the island of Maradu is all of sand formation, a little beach rock indicating a former washing-away of its eastern shores, which now seem almost stationary.

Faidu and **Gan** resemble Maradu, but Gan runs out into a great flat, half-a-mile broad, across which lines of rock extend out to the boulder zone. The latter is in this part of the

atoll very much diffused over the flat, which nowhere at low tide has more than a foot of water. The extraordinary point about this reef is the presence of seven small uncharted islands between Faidu and Gan and the seaward edge of the reef. The first of these is a small stony islet just inside the boulder zone opposite the centre of Gan. Then there is a sand-bank in the corresponding position off the W. end of Gan. On the seaward side of the E. end of Faidu there is a good deal of fallen timber, showing washing away, and between the island and the boulder zone are no less than 15 masses of rock on the reef. Off the centre of Faidu, and opposite the passage between Faidu and Maradu, was a large coconut-covered island, with outside it three smaller islets covered with low bushes, an additional stone bank with a few shrubs lying to the N.

It is important to consider the formation of these additional islands, all of which at some point touch the boulder zone. Unfortunately I was unable to visit them, but they certainly seemed to have been formed of loose boulders and sand, piled up by the waves. I cannot by the study of the chart bring myself to believe or imagine that these islands may have been formed by the washing away of the land behind them, nor that they can have existed when the chart was made. I think it is more than probable that the land behind them has washed away somewhat since 1835, but of any considerable action there are no traces, such as would be bound to be left on the reef if these islets had been formed in this way. It is most remarkable that this fresh formation of land should have occurred on this area alone in the atoll, the action being evidently purely local and isolated. Considering the whole formation, I am driven to the perhaps rather lame conclusion that the physical conditions in the S.W. of the atoll differ from those in other parts sufficiently to have in the first place produced a broad reef-flat, largely by the washing away of the land, which loss is now being repaired by the formation of a fresh series of islands along the boulder zone of the reef. This of course suggests a possible fresh origin for kuli, but those of the E. rim were certainly not formed in this manner.

XII. Other Atolls.

I only caught a fleeting glance of the south-east rim reefs of Ari atoll, but from native accounts I have no doubt but that the bank closely resembles the two Nilandu atolls. We anchored for one night to the south of Mahiaddu (lat. 3° 46′ N.) in the entrance to the broad passage of which we found two shoal patches growing up, with respectively 3 and 5 fathoms.

Wattaru atoll differs in no respect from the chart, save that there are now islands with coconut-trees on either side both east and west of its single channel to the south. According to native accounts Fua-Mulaku has a pool or kuli of fresh water in the centre with strange fish, and the lagoon of Makunadu is said to be both considerably larger and deeper than appears in its chart. Toddu, Karidu, Alifuri, Tiladumati, and Ihavandifolu were not visited either by my companion or myself. They are extremely unlikely, however, to present any points of interest, except perhaps in their outer slopes, that have not already been considered in other atolls.

APPENDIX C.

Concluding Remarks and Notes.

In concluding my account of the Coral Reefs of the Maldives, the investigation of which was the main object of my expedition to that Archipelago, it is fitting that I should state and acknowledge the personal help and assistance I have received.

In the first place I would express my great indebtedness to all my teachers and colleagues in the Zoological Laboratory at Cambridge. It would be invidious were I to mention any name besides that of Mr Adam Sedgwick, to whose constant sympathy is mainly due any merit that my investigations may have. In particular I am obliged to him for reading over Chapters v.—vii. of this Paper and for much most valuable and suggestive criticism.

To the expert knowledge of Adm. Sir W. Wharton, Chief Hydrographer, Sir John Murray, and Mr J. Y. Buchanan I owe much. The first gave me most valuable advice as to navigation, seasons, etc. from which I drew up my itinerary, besides lending me many valuable instruments. I have had on three occasions the advantage of "thrashing out" the question of Coral Reef Formation with Sir John Murray. I am pleased that my investigations in the main support his theory, a result which I did not consider probable when I left home for the Maldives.

Prof. Hickson, Prof. Judd, Prof. Herdman, Mr W. T. Blanford and other experts have given me valuable help in considering various points. They will find replies to some of their criticisms in Appendix A. With my companions on the Expedition, Mr L. A. Borradaile and Mr Forster Cooper, I have discussed most points that have arisen, and the former has read through my manuscript. To those gentlemen, who are so kindly working out my collections, I would express my sincerest gratitude; the results of the Expedition would be of little value without their aid.

I account it a great good-fortune that I have been followed both in Fiji and in the Maldives by Prof. Alex. Agassiz, the greatest and most experienced authority on all questions connected with Coral Reefs. I am greatly obliged to him for allowing me to discuss their formation with him on several occasions previous to his visit to the Maldives. My work dealing mainly with the surface waters (down to 50 fathoms) will, I trust, form a complement to his deeper-water investigations. I have tried to give all the facts without prejudice, but no doubt at least some of my views may have to be modified. In particular the occurrence of manganese nodules in the deeper waters of the Maldives is a fact of no small interest as bearing on the probable character of the foundation rock on which the group has been built.

No doubt Prof. Agassiz's full account will shortly be published, but I may be permitted to quote the summary of his soundings between the banks[1]. "Our soundings showed a greatest depth of 251 fathoms in the center of Gallandu Channel, which separates Ihavandiffulu from Tiladumonati; 769 fathoms in the center of the channel between Miladummadulu and Fadiffolu." "We found 302 fathoms between Goidu (Horsburgh atoll) and South

[1] *Amer. Jour. Sci.* ser. 4, vol. 13, pp. 300–1 (1902).

Malosmadulu. In the center of Kardiva Channel on the two sides of Kardiva island we obtained 312 and 298 fathoms with 372 fathoms one-and-a-half miles south of Fadiffolu atoll. One hundred fathoms was obtained in the center of the channel between Gafaru and North Male. Between North and South Male in the center of Wadu Channel we got a depth of 260 fathoms[1]. In the center of Fulidu Channel separating South Male and Felidu atoll we found 374 fathoms. In the channel north of Wattaru Reef we found 283 fathoms; in Wattaru Channel between Wattaru reefs and Mulaku atoll 253 fathoms, and between Mulaku and Kolumadulu the depth in the center of the channel increased to 648 fathoms. Returning now to the groups of the western chain of atolls we found 231 fathoms in the Ariyaddu Channel between Ari and North Nilandu. The charts indicate 200 fathoms in the center of the channel between North and South Nilandu, and between it and Kolumadulu, the northernmost of the southern single chain of atolls, we found 251 fathoms in the center of the channel.

"In the wider channels separating the atolls of the southern single chain the depths become much greater. In the center of the Veimandu Channel, which separates Kolumadulu and Haddumati, the depth had increased to 1118 fathoms, and halfway between it (Haddumati) and Suvadiva we found a depth of 1130 fathoms. In the wide channel between Suvadiva and Addu we found 1292 fathoms a little to the north of Fua Mulaku, and 1048 fathoms between it and Addu. At a distance of four-and-a-half miles to the south of Addu we ran into 718 fathoms."

In the body of this Paper, particularly in Chapter VI. on North Mahlosmadulu, I have laid great stress on the changes shown by the islands, reefs and faro since the original survey of Capt. Moresby in 1834–6. Any single change might well be due to an error, but *the vast majority* of these small differences point in the same direction. I accordingly maintain that these diversities show real changes and indicate the actual development now going on in the Maldive Group. Even without the comparison with the original charts the facts, if correctly stated above, as to the changes now in progress are sufficient to prove most of the changes, which the comparison perhaps more clearly brings out. Even for Addu Atoll, which so markedly differs from the rest of the banks, I cannot but suppose that the alterations found are real ones. Adm. Sir W. L. Wharton, however, when I lectured before the Royal Geographical Society, sounded a note of caution[2], which his high authority impels me to quote at length. "There is one point I think I ought to mention. I do not quite think that Mr Gardiner can rely so implicitly as he does upon the exact accuracy of the shape of these little atollons (faro) in the Maldives as they were mapped by Capt. Moresby. If you come to think of it, this long line of islands extends for nearly 500 miles in a double line and over considerable width, and was mapped during three seasons in a small sailing vessel, and it is quite impossible—I know what the system of surveying of that day was—is quite impossible that the reefs could have been more than very, very roughly sketched." "In a great many cases it is noted down in the original surveys 'depth given by the natives,' 'depth reported,' and so on. This has (sometimes) been left out in the published chart to simplify matters."

Of other questions not already dealt with in the body of this paper a reference may be made to the food of the reef-building corals, on which a number of observations were

[1] I take this opportunity of correcting an error on p. 11, line 2 of the "Introduction" to this Publication in respect to the single *deep* sounding we made; for "S.W. ¼ W." read "S.E. ¼ E."

[2] *Geogr. Jour.*, vol. XIX. no. 3, p. 297 (1902).

carried out. These served fully to confirm my previous work on the subject, but most reef-corals evidently ingested a certain amount of organic food, although the vast majority undoubtedly obtained their nutriment principally through the agency of their commensal algae. The polyps of such genera as *Euphyllia* and *Prionastraea*, in which no definite gastrovascular cavity seems to be present, seized fragments of weed and animal matter when placed by me within their reach. The presence of dead organic matter in about 1 or 2 per cent. of the preserved polyps of *Pocillopora* and *Astraea* points to the same method of feeding sometimes occurring in nature, although there seems no doubt but that these same corals feed mainly by means of their commensal algae.

The occasional death of all the species of corals over considerable areas of the reefs by silting up after heavy gales and cyclones is well-known, and was observed by us in several places. I would emphasize the fact that in such cases practically all the coral colonies of all the genera found in the area are killed. In addition separate coral colonies may be here and there found killed by such a cause, probably by some purely local change. Usually the absence of corals, etc. on reef-flats, in other respects suitable for their growth, seems to be due to the waves and currents in such places moving fine material from the reefs and shores. A series of experiments on transplanting corals to barren areas was entirely unsuccessful so far as the growth of the animals was concerned, the colonies, when not washed away, being *in every single place* killed by silt.

A number of experiments were carried out on the exposure of colonies of several genera of reef-corals to the air and sun. The living masses of various genera differed enormously, but all, so long as they had some part of their polyp layers kept constantly moist by (*i.e.* immersed in) the water, appeared to be able to live for at least 5 hours, even when exposed to the full force of the sun. The colonies of most genera when placed on the beach for the whole night or for 1—2 hours in the full force of a tropical sun were quite capable of expanding again when returned to the water. These experiments point to the fact that the ordinary exposure—or even the extraordinary exposure after heavy winds—of corals on the reef at low tide to the air and sun does not kill or otherwise destroy such coral colonies as may stand up out of the water.

Yet the death of coral colonies on reefs is of common occurrence, and has been mentioned by most authors. In the Pacific, as well as subsequently in the Maldives, I frequently observed separate, dead coral colonies, as well as the death of all the colonies of *individual species* of corals over relatively wide areas. In the majority of these cases the separate corallites did not appear to have been in any way silted up, nor were many of the colonies in such positions that they could by any possibility have been killed by exposure either to air or sun. Separate dead colonies also were often found where neighbouring colonies of the same and other species of all sizes were flourishing. They were generally of considerable size, and in the absence of any visible environmental cause, I am inclined to assign their death to senile decay, a phenomenon I have found well-marked in *Flabellum* and other corals.

An entirely different case is where the dead skeletons only of a single species of coral were found on one reef, while on the next the colonies of the same species were perchance growing luxuriantly. At the time I did not appreciate the importance of this phenomenon, but I recorded in my notes a large number of instances of the absence from particular areas of living colonies of individual common species of corals, while the dead coralla of the same species were common. I have already given a few instances and, to some degree, discussed

the subject in a paper entitled, "Some Notes on Variation and Protandry in *Flabellum rubrum* and Senescence in the same and other Corals[1]," but I draw further attention to it here, in the hope that future visitors to coral-reef regions will pay attention to the subject. "If—as I am impelled to believe—the ripening of the generative organs of a large number of polyp colonies of the same species in a single locality or habitat, followed by the subsequent death of all these colonies, is a regular phenomenon, the consequences must be of the most wide-reaching importance in the formation of coral reefs." "Remembering the occurrence of a ciliated larva in the Madreporaria, it is impossible to believe that the colonies of a single species in any area are of the same age—they certainly are not of the same size, and hence have not a like number of polyps. It is consequently necessary to suppose that in an area—owing probably to some change in the physical conditions of their environment—all the corals of some single species have been stimulated to ripen and dehisce their generative products at the same time, the act leading ultimately to their weakening and death." The only analogous case that I know of in nature is that of the bamboo, every plant of which in a district produces its fructification at the same time and dies[2]. The analogy is not complete, however, for whereas the individual polyps of a colony go on producing ova or spermatozoa during the whole of their life, the bamboo merely sets one enormous fructification, which apparently uses up all its energy and causes its death.

At the last meeting of the British Association, and in the last Part of this Publication[3], I discussed to some extent the importance of algae as agents in the disintegration of corals. As I go to press I have to thank Mr J. E. Duerden for an important paper on this subject, which he has been kind enough to send me. Mr Duerden's conclusions, derived mainly from the examination of W. Indian corals, are strikingly in accordance with mine, and go much further with regard to this one class of organisms. Mr Duerden[4] found in 30 W. Indian corals that he examined the tubes of algae of the genera *Gomontia* and *Ostreobium* penetrating every part of the different coralla, but their living filaments were only present in the more superficial parts of the different colonies, to which alone light could penetrate. Twelve fragments of coral, obtained by Prof. Agassiz in the Pacific in 1899—1900, when decalcified revealed in every case the presence of filamentous algae. "The results presented above give good reason for assuming that in general all corals are infected with boring algae, even to their most superficial regions of growth." "Once a coral is attacked by these (algae), the growth of the ramifying filaments apparently never ceases so long as the necessary conditions of plant life remain; even when the dead coral is broken up into fragments the growing filaments still continue their corroding action on the separate particles, and by the production of soluble bicarbonates lead to their ultimate disappearance."

[NOTE. For an account of the biology and species of the reef-building plants see "The Lithothamnia of the Maldives and Laccadives," by M. Foslie in the same Part of this Publication.]

[1] *Proc. Camb. Phil. Soc.* vol. XI. pp. 463—71 (1902).

[2] Mr W. T. Blanford in a letter remarks that he has "seen more than one instance of a particular species of bamboo having perished over hundreds of square miles of country." He further points out that the bamboos are wild plants, whereas in the paper already referred to I unintentionally inferred that the phenomenon was found only in cultivated ones.

[3] *Vide* p. 325, and also p. 116 in Part 2.

[4] "Boring Algae as Agents in the Disintegration of Corals," *Bull. Amer. Mus. Nat. Hist.* vol. XVI. pp. 323—332 (Sept. 25, 1902).

MARINE CRUSTACEANS.

PARTS IV.—VII.

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(With Plate XXII. and Text-figures 110—119.)

IV. SOME REMARKS ON THE CLASSIFICATION OF THE CRABS.

When Boas, in 1880[1], reorganised the classification of the Decapoda, abolishing the distinction established by Fabricius between the *Macrura* and *Brachyura*, and dividing the order anew into *Natantia* (Prawns and Shrimps) and *Reptantia* (Lobsters and Crabs), he left the crabs (*Brachyura*) unnumbered as a single tribe of the Reptantia. Within this tribe he recognised two subtribes, the comprising the primitive *Dromia*-like forms, in which the orbits, the abdominal limbs, the gills and other features recall the Macrurous tribes, and the other containing all the rest of the true crabs. These subtribes he called respectively *Dromiacea* and *Brachyura genuina*. Ortmann, however, elaborating Boas' scheme in 1896[2], took the step of dividing the Brachyura into three groups, each of which he made equal in rank to the other subdivisions of the Reptantia, *Astacidea*, *Loricata*, etc. These groups were: (1) Boas' Dromiacea, under the name of *Dromidea*; (2) the old division *Oxyrhynchus* established by Milne-Edwards for the crabs like *Calappa* and *Leucosia*, which are modified for life in sand, and (3) the *Brachyura*, comprising the remainder of the crabs. In the *Brachyura* he recognised, with some alterations, Milne-Edwards' divisions *Oxyrhynchus* (Spider Crabs), *Cyclometopa*[3] (Round-fronted Crabs, including *Cancer*-like genera), and *Catametopa* (Square Crabs).

It may be admitted that Ortmann was well-advised in establishing his three main groups of Crabs. If he be right—as in the opinion of the writer of this paper he is right—in regarding the Oxyrhynchs as derived from the Dromiacea independently of the Brachyura genuina, then it is clearly misleading to retain Boas' arrangement, in which the Dromiacea

[1] Boas, J. E. V., *Kong. Danske Videnskab. Selsk. Skrifter* (6), x. p. 33.

[2] Ortmann, A. E., *Zool. Jahrb. Syst.* ix. p. 486.

[3] Ortmann, as first applied the name *Cancroidea* to this group, but *Cyclometopa* forming only a part of Milne-Edwards' group of the same name, Lauer Brown's *Tunicata*, Crust. x. p. 1265, he returned to the use of the term *Cyclometopa* as meaning all its former genera, making a new synonymous with *Cancroidea*.

are opposed to a group containing the Oxystomes together with the rest of the crabs. But quite apart from this consideration is the fact that the Oxystomata have certain well-defined features which give them a unity such that it would in any case be necessary to oppose them to the rest of the Genuina; and, if this be not done by raising them to the rank of the Dromiacea, then a new grade of classification must be introduced within the Genuina, which must be separated into Oxystomes and non-Oxystomes. Such a step would be most undesirable in view of the already complicated system of the Decapoda.

At the same time I am unable to follow Ortmann in raising the three groups of crabs to the same rank as the Astacidea or Paguridea. The crabs are a true group with a common phylogenetic origin from Macrurous forms of the Reptantia through the Dromiacea. Moreover, besides the shape of the body, there are three features which are almost absolutely diagnostic of the Brachyura in the old sense of the word: (1) the loss of the last pair of abdominal limbs, (2) the fusion of the shield of the cephalothorax with the epistome in such a way as to form two sockets for the sense organs of the two sides, and (3) the broad, unjointed endopodite of the first maxilliped, with its marked outer angle (Fig. 110). In these circumstances I follow Boas in keeping all the crabs together as a single tribe, *Brachyura*, of the Reptantia. If we thus use the word in its old, full sense, it becomes needful to find another name for Ortmann's Brachyura (= Boas' Brachyura genuina without the Oxystomata). For this group I have already proposed[1] to use de Haan's name *Brachygnatha*.

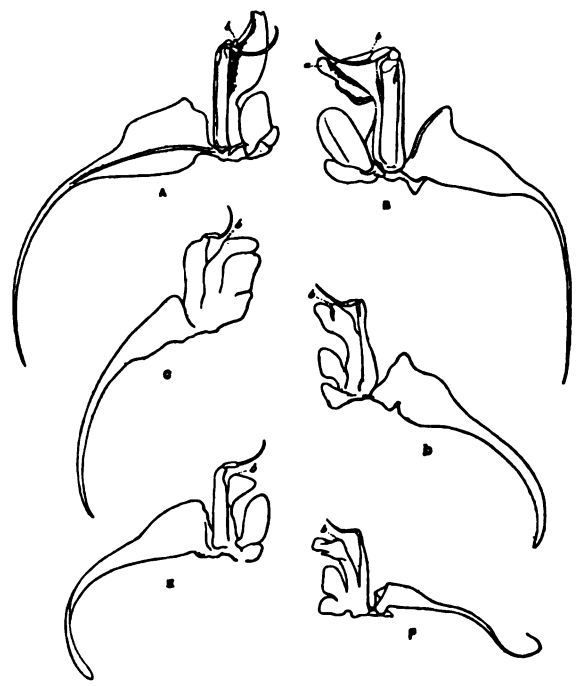


FIG. 110. The first maxillipeds. A. *Calappa*, B. *Portunus*, C. *Dromia*, D. *Cardiosoma*, E. *Cancer*, F. *Uca* (= *Gelasimus*), *a*. the inner lobe characteristic of the Portunidae, *b*. the outer angle, well-marked in crabs.

I now pass to the consideration of the subdivisions of the Brachygnatha. The Oxyrhyncha form a natural and, on the whole, well-defined group, but a boundary between the Cyclometopa and the Catometopa is absolutely wanting. This is especially the case between the Gonoplacidae and the Xanthidae, where the transition is made complete by such genera as *Pilumnoplax* and *Platypilumnus*. The Potamonidae also are far from presenting an easy problem in their affinities. And the genus *Catoptrus*, while it seems clearly allied with the Carcinoplacinae, is extraordinarily like the Portunidae, this likeness extending even to the form of the first maxilliped, which is peculiar to the latter family (B. Fig. 110). In view of these facts I propose to unite the Cyclometopa and Catometopa into a single group, for which I propose the alternative titles *Brachyrhyncha* and *Cancroidea*[2], corresponding

[1] *Proc. Zool. Soc.* 1900, p. 568. This term in its original meaning included the Dromiacea as well as the Cancroid forms, but it has so long been in disuse that its revival in a somewhat altered sense would cause no inconvenience.

[2] This word was used by de Haan (in von Siebold's "Fauna Japonica") with practically the same meaning as that given to it here.

to those applied to the spider crabs, *Oxyrhyncha* and *Maioidea*. The group thus formed presents a series of families, long and varied indeed, but neither more numerous nor more diverse than, for instance, those included in the Caridea (Eukyphotes).

With regard to the position of the remarkable family Hymenosomidae I am in agreement with Ortmann in provisionally placing them among the Oxyrhyncha. The genus *Catoptrus* A. M.-Edw., 1870 (= *Goniocaphyra* de Man, 1887), which I have already[1] proposed to make the type of a subfamily of the Portunidae, I shall for the present continue to keep in that position, in spite of the fact that, if *Catoptrus* seems clearly related to *Carupa* and perhaps also to *Caphyra* among the swimming crabs, it has hardly less clear resemblances to *Libystes* and *Carcinoplax* among the Gonoplacidae. The Hapalocarcinidae should, I believe, be placed somewhere among the Brachyrhyncha but, in view of their exceedingly doubtful affinities, are not included in the key given below. For the same reason the family Trichiidae, which should probably be established for *Trichia* de Haan is also left unmentioned. Lastly, I have followed Alcock in placing *Palicus* near the Catometope families. The accompanying table gives the classification of the Brachyura, as it will stand with the changes proposed above, and the characters on which it depends are summarised by means of a series of keys.

Subtribes of the Brachyura.

I. Fore edge of the mouth-field (endostome) prolonged forwards to form a gutter. [Last pair of legs normal or abnormal. Female opening generally sternal. First abdominal limb of female wanting. Gills few.] *Oxystomata*[2].

II. Mouth-field roughly square.

A. Last pair of legs abnormal, dorsal. Female genital opening coxal. First abdominal limb of female present. Gills usually many. *Dromiacea*[2].

B. Last pair of legs normal, rarely reduced, not dorsal, except in *Palicus* and *Ptenoplax*. Female genital opening sternal. First abdominal limb of female wanting. Gills few. *Brachygnatha*.

Legions of the Brachygnatha.

I. Fore part of body narrow, usually forming a distinct rostrum. Body more or less triangular. Orbits generally incomplete. *Oxyrhyncha*[2].

II. Fore part of body broad. Rostrum usually reduced or wanting. Body oval, round or square. Orbits nearly always well enclosed. *Brachyrhyncha*.

Families of the Brachyrhyncha.

I. Orbits formed but more or less incomplete. [Antennal flagella, when present, long and hairy. Rostrum present. Body elongate-oval. Fore edge of the mouth indistinct.] *Corystidae*.

II. Orbits complete (though fissures may remain), except in the Mictyrinae, where the eyes are almost or quite unprotected. [Body rarely elongate-oval. Rostrum often wanting. Antennal flagella usually short, not hairy.]

[1] *Proc. Zool. Soc.* 1900, pp. 578, 799.

[2] For key see the article on the group.

TABLE SHOWING THE DIVISIONS OF THE BRACHYURA.

Tribe	*Sub-tribes*	*Legions*	*Families*	*Subfamilies*
Brachyura	Oxystomata		Calappidae	Calappinae
				Orithyinae
				Matutinae
			Leucosiidae	Leucosiinae
				Iliinae
			Raninidae	
			Dorippidae	Dorippinae
				Tymolinae
	Dromiacea	Dromiidea	Homolodromiidae	
			Dromiidae	
			Dynomenidae	
		Homolidea	Homolidæ	
			Latreillidae	
	Brachygnatha	Brachyrhyncha	Corystidae	
			Atelecyclidae	Thininae
				Acanthocyclinae
				Atelecyclinae
			? Trichiidae	
			Cancridae	Pirimelinae
				Cancrinae
			Portunidae	Carcinidinae
				Portumninae
				Catoptrinae
				Carupinae
				Portuninae
				Caphyrinae
				Thalamitinae
				Podophthalminae
			Potamonidae	
			Xanthidae	Xanthinae
				Carpilinae
				Etisinae
				Menippinae
				Trapeziinae
				Eriphiinae
				Oziinae
			Gonoplacidae	Carcinoplacinae
				Gonoplacinae
				Prionoplacinae
				Rhizopinae
				Hexapodinae
			Pinnotheridae	(subfamilies ?)
			Grapsidae	Grapsinae
				Varuninae
				Sesarminae
				Plagusiinae
			Gecarcinidae	
			Ocypodidae	Ocypodinae
				Macrophthalminae
				Mictyrinae
			Palicidae	
			Ptenoplacidae	
			? Hapalocarcinidae	
		Oxyrhyncha	Parthenopidae	Parthenopinae
				Eumedoninae
			Maiidae	Inachinae
				Acanthonychinae
				Pisinae
				Maiinae
			Hymenosomidae	

A. Carpopodite of 3rd maxilliped articulates at or near the antero-internal angle of the meropodite. [Body usually round or transversely oval. Male opening nearly always coxal.]

1. Legs more or less distinctly adapted for swimming. [Antennules fold slanting or transverse. Usually a small lobe on the inner angle of the endopodite of the 1st maxilliped[1].] *Portunidæ.*

2. Legs not adapted for swimming. Or, if so modified, then the vas deferens opens sternally or runs in a sternal groove (certain *Macropipidæ* and *Libystes*). Inner lobe on the endopodite of the first maxilliped wanting[2].

a. Freshwater crabs with the branchial region much developed and swollen. [Body often squarish, but male opening coxal.] *Potamonidæ.*

b. Marine crabs, with the branchial region not greatly swollen.

i. Antennules fold lengthwise.

α. Carapace subcircular. Antennal flagella either long and hairy or wanting. *Atelecyclidæ*[3].

β. Carapace broadly oval or hexagonal. Antennal flagella present, short, not hairy. *Cancridæ*[3].

ii. Antennules fold slanting or transversely.

α. Body usually transversely oval. Male openings rarely sternal. Not sharply separated from the following family. *Xanthidæ*[4].

β. Body usually square or squarish. Male ducts open on the sternum or, if coxal, pass along a groove in the sternum. Not sharply separated from the foregoing family. *Cyclodromidæ.*

B. Carpopodite of 3rd maxilliped does not articulate at or near the inner angle of the meropodite. [Body usually square or squarish. Male opening sternal, except in *Ptenoplax*, where the duct passes along a sternal groove to the coxopodite.]

1. Small symbiotic crabs with very small eyes and orbits. Body usually more or less rounded. *Pinnotheridæ.*

2. Free-living crabs with eyes not specially reduced and usually a square body.

a. Last pair of legs dorsally placed and weaker than the others. [Interantennular septum very thin. No distinct epistoma. Exopodite of 3rd maxilliped not hidden.]

i. Front narrow. Female opening in normal position. 3rd maxillipeds subpediform, not covering the mouth. *Pseudothelphusidæ.*

ii. Front moderately broad. Female openings on the sternal segment corresponding to the pair of walking legs. 3rd maxillipeds cover the mouth ventrally and have a very small meropodite. *Trichodactylidæ.*

[1] A key to the subfamilies of the Portunidæ will be found in the *Proc. Zool. Soc.* (1907), p. [illegible]. The name *Carcinus* should be substituted for *Somanniathelphusa* in the Potamonidæ, the name *Carcinus* having priority in Potamonidæ in 1821.

[2] I make this statement on the authority of Gerstaecker (*Zool. Jahrb.* [illegible]). [illegible] and many other genera have a small lobe on the inner side of the endopodite, but this is not at the angle and is a different structure. In *Cardisoma* the inner angle is divided from the main part of the plate, thus having a *large* inner lobe. This lobe is probably not the same structure as that in the Portunidæ (Fig. [illegible]).

[3] For key to subfamilies see below.

[4] A key to the subfamilies of the Xanthidæ will be found above on p. 388 of Pt. III. in the article on this family.

β. Last pair of legs not dorsally placed nor markedly weaker than the rest. [Inter-antennular septum not very thin except in Macrophthalminae.]

i. A gap of greater or less size is left between the 3rd pair of maxillipeds. Front broad, or moderately so.

a. Sides of the body either straight or very slightly arched. Shape square. Rarely true land-crabs. *Grapsidae*[1].

β. Sides of the body arched. Shape transversely oval. Land crabs. *Gecarcinidae.*

ii. 3rd pair of maxillipeds almost or quite close to the mouth. Front moderately or very narrow. *Ocypodidae.*

Subfamilies of the Atelecyclidae.

I. Antennal flagella absent. [Mouth covered by 3rd maxillipeds. Front uncleft.] *Acanthocyclinae.*

II. Antennal flagella present.

A. Regions not defined. 3rd maxillipeds cover the mouth. Front entire or lobed. *Thiinae.*

B. Regions more or less clearly marked out. 3rd maxillipeds do not cover the mouth. Front toothed. *Atelecyclinae.*

Subfamilies of the Cancridae.

I. Carapace broadly oval. Epistome not sunken. *Cancrinae.*

II. Carapace hexagonal. Epistome sunken. *Pirimelinae.*

V. THE CRABS OF THE CATOMETOPE FAMILIES.

The group Catometopa was as hard to characterise bionomically as it was to separate morphologically from the Cyclometopa. The one thing that could be said about it in this respect was that the bulk of its members lived, not in the sea, but on land, in fresh water or between tidemarks. At the same time a considerable number were strictly marine, especially the Xanthid-like family Gonoplacidae and the Mussel-Crabs of the Pinnotheridae. The land forms have been already enumerated above (Pt. I. p. 64) where some remarks on their habits will be found. Of the others, the only genera to which any striking bionomic interest attaches are *Plagusia* and *Leiolophus*, which live between tidemarks and are very active (see p. 432), *Pinnotheres*, which inhabits bivalve shells, and *Planes*, found on floating objects at sea. *Caecopilumnus* described with the Xanthidae, etc. (p. 267), belongs, I think, to the Gonoplacidae. *Platyozius* described in the same paper is more nearly related to *Pilumnoplax* than to *Pseudozius* but is a Xanthid, as is also *Pilumnoplax.*

All the species which are not new have already been described from the Indo-Pacific region, most of them being Indian. The following list enumerates the species:

[1] A key to the subfamilies and genera of the Grapsidae is given by Kingsley (*Proc. Ac. Philad.* 1880), and the members of most other groups of the old Catometopa can be fairly easily recognised by means of the diagnoses in Major Alcock's paper (*Journ. As. Soc. Bengal*, LXIX. ii. 1900). The points in which the arrangement in this paper differs from Major Alcock's are mostly small and will cause no confusion.

Family **Gonoplacidae.**

Subfamily **Carcinoplacinae.** Genus *Litocheira* Kinahan, 1858.

1. *Litocheira angustifrons* Alc., 1902. Alcock, VI. p. 315[1].

Taken on the reef at Hulule, Male Atoll.

2. *Litocheira integra* (Miers), 1884. Alcock, VI. p. 314.

Taken on the reef at Hulule, Male Atoll. *L. subinteger* (Lanchester), 1900 [= *Carcinoplax integer* de Man, 1887] seems to differ from this species in that: (1) There are three, instead of two, notches on the anterolateral edge. (2) The shape of the anterolateral edge is different, making almost a right angle. (3) The front is narrower.

3. *Litocheira inermis* n. sp. (Fig. 111).

Diagnosis: "A *Litocheira* whose cephalothorax is almost square, smooth, hairless and microscopically pitted; the front arched gently, but with a shallow bay in the middle; the anterolateral edges without teeth but showing traces of two faint notches; the chelipeds short and stout, with one sharp tooth at the inner angle of the wrist and a faint ridge along the lower part of the outside of the hand; and the walking legs stout, with broad end-joints and a beard of hairs on the hinder edge of the last two joints."

Length of the only specimen (a female): 8·5 mm. Breadth: 9·5 mm. Colour in spirit: yellowish-white.

One female was taken at Hulule, Male Atoll.

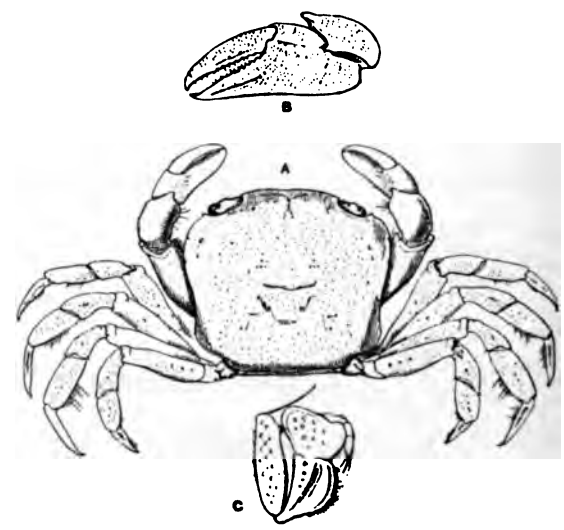


FIG. 111. *Litocheira inermis*; A. whole animal, B. outside of hand, C. third maxilliped.

Subfamily **Rhizopinae.** Genus *Selwynia* n.

Among the crabs collected on the reef at Hulule, Male Atoll, was one which by its diagnostic features should belong to the Rhizopinae, but for which I am unable to find a place in any of the known genera of that subfamily. In proposing a new genus for it I have commemorated my College and its patron saint.

Characters of *Selwynia* n. gen.: (1) *Carapace* breadly oval, without teeth or notches on the anterolateral edge, flat, but falling away in front. Body rather deep. (2) *Front* narrow, bent downwards, bilobed owing to a deep groove in the middle, continued into the interantennular septum. (3) *Eyes* well formed and well pigmented, small, stout, not fixed into the small, close-fitting orbits. (4) *Antennules* fold almost, but not quite, transversely. (5) *Antennae* short, the flagellum standing in the orbital gap. (6) *Third maxillipeds* with meropodite roughly square, a little smaller than the ischiopodite; palp strong, arising nearly

[1] For the principle upon which references are given in this paper see p. 192 of Pt. II. of this publication. Major Alcock's paper on the Indian Catometopes appeared in *Journ. Roy. As. Soc. Bengal*, LXIX. ii. (1900).

in the middle of the fore edge of the meropodite; and exopodite well developed. (7) All the *legs* present and stout. (8) *Abdomen* not nearly covering the last thoracic sternite.

4. *Selwynia laevis* n. sp. (Fig. 112).

Diagnosis: "A *Selwynia* with the body smooth and naked except for some hairs on the underside and on the last three joints of the walking legs, microscopically pitted all over; the regions of the back barely to be made out, the chelipeds very large and stout, their fingers nearly as long as the palm, gaping slightly, finely toothed on their opposed edges, and not furrowed; no thorns or teeth on any of the joints of any leg, save a small tooth underneath the meropodites of the walking legs; and the walking legs very stout, with very small end-joints, the last pair being a good deal smaller than the rest."

Length of the only specimen (a male): 6 mm. Breadth: 8 mm. Colour in spirit: white.

One male specimen was taken at Hulule, Male Atoll.

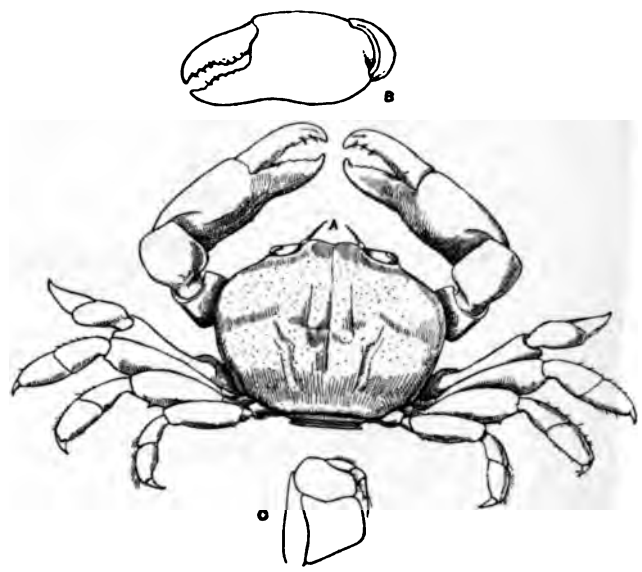


FIG. 112. *Selwynia laevis*; A. whole animal, B. outside of hand, C. third maxilliped.

[Genus *Caecopilumnus* Borradaile, 1902.]

[*Caecopilumnus hirsutus* Borradaile, 1902.] See above, Pt. III. p. 267.

This genus is at least allied to, if not identical with, *Typhlocarcinodes* Alc., 1900. I formerly regarded it as *incertae sedis*, but now believe that its proper place is in this subfamily.

Family **Pinnotheridae.** Genus *Pinnotheres* Latr., 1802.

5. *Pinnotheres purpureus* Alc., 1900. Alcock, VI. p. 339.

Dredged from 30 fathoms, Felidu Atoll.

6. *Pinnotheres tenuipes* n. sp. (Fig. 113).

Diagnosis: "A *Pinnotheres* with the carapace subcircular, smooth, moderately convex; the front rounded and hood-like; the eyes small, well pigmented; the end-joint of the third maxilliped slender, set far back on the inner edge of the joint before it, nearly reaching the tip of that joint; the chelipeds short, moderately stout, with fingers about $\frac{2}{3}$ the length of the palm, and a strong, rounded tooth on the moveable one about $\frac{1}{3}$ of its length from the articulation; the walking legs slender, the second the longest, the second and third nearly equal, and the fourth much the shortest, the last two joints of the walking legs hairy and their end-joints about equal in length, except for those of the fourth pair, which are much longer and more slender than the rest."

Length of the only specimen (a female): 12 cm. Breadth: 13 cm. Colour in spirit: mottled brown.

One female was taken from within the shell of a *Mya* (?) in Minikoi.

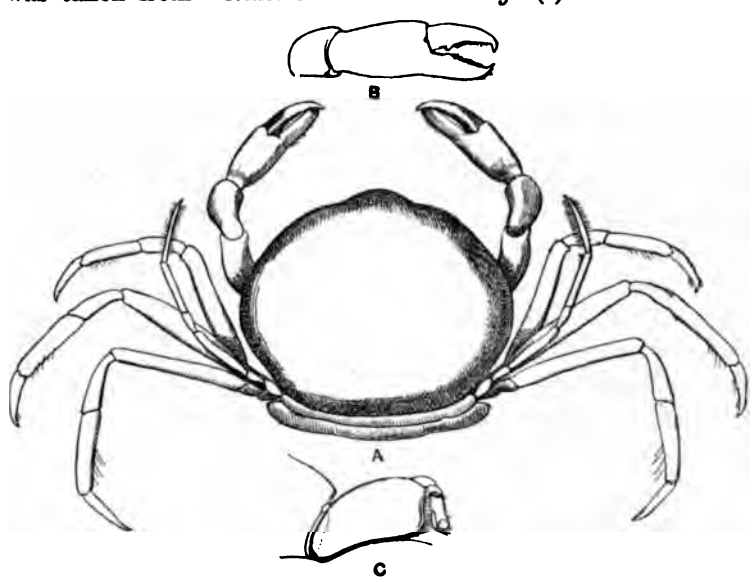


FIG. 113. *Pinnotheres tenuipes*; A. whole animal, B. outside of hand, C. third maxilliped.

Family **Grapsidae.**

Subfamily **Grapsinae.** Genus *Pachygrapsus* Randall, 1839.

7. *Pachygrapsus minutus* (A. M.-Edw.), 1873. Alcock, VI. p. 379.
Taken at Minikoi, and dredged in Fadifolu and Mahlos Atolls down to 25 fathoms.

8. *Pachygrapsus plicatus* (H. M.-Edw.), 1837.
Pachygrapsus plicatus, Kingsley, *Proc. Ac. Philad.* 1880, p. 200.
Taken at Hulule, Male Atoll and Goidu, Goifurfehendu Atoll.

9. *Pachygrapsus planifrons* de Man, 1887.
Pachygrapsus planifrons de Man, *Arch. Naturges.* LIII. i. p. 368, Pl. XVI. Fig. 2 (1887).
Taken in a coral mass on the outer reef at Minikoi.

Subfamily **Varuninae.** Genus *Planes* Leach, 1815.

10. *Planes minutus* (Linn.), 1750.
Nautilograpsus minutus, Kingsley, *Proc. Ac. Philad.*, 1830, p. 202.
Taken at Male on a floating cuttle-bone.

Subfamily **Plagusiinae.** Genus *Plagusia* Latr., 1806.

11. *Plagusia depressa* (Hbst.), 1793, var. *squamosa* (Hbst.), 1790. Alcock, VI. p. 437.
Common all over the Archipelagoes, scrambling actively over the rocks at low tide.

Genus *Leiolophus* Miers, 1876.

12. *Leiolophus planissimus* (Hbst.), 1804. Alcock, VI. p. 439.

Common all over the Archipelagoes. Hides under stones, clinging with its flat body close against them. When the stone is turned, the crab slips away, and is hard to secure.

Family **Ocypodidae.**

Subfamily **Macrophthalminae.** Genus *Macrophthalmus* Latr., 1829.

13. *Macrophthalmus verreauxi* H. M.-Edw., 1848. Alcock, IV. p. 377.

Taken in Felidu Atoll, 30 *f.*

14. *Macrophthalmus latipes* n. sp. (Fig. 114).

Diagnosis, "A *Macrophthalmus* whose length is to its breadth as 5 : 8; with the front very strongly bent downwards; the upper edge of the orbit slightly sinuous, slanting so much backwards that the sharp thorn at its outer angle lies far behind the level of the front; no stridulating organ; the antero-lateral edge with one blunt tooth behind the orbital angle and faint traces of two mounds behind this tooth; eyes outreaching the orbital angle by more than a third of their length; chelipeds small, simple in shape, with one blunt tooth on the moveable finger and no thorn on the inside of the palm; and walking legs with a spine near the end of the upper edge of the meropodites and long slender end-joints, except in the case of the hindermost pair, where the last three joints are broad and flattened."

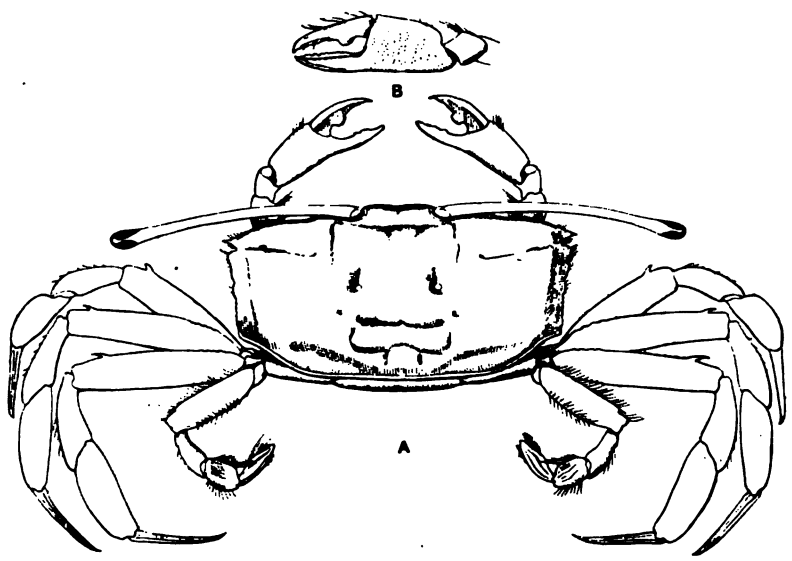


FIG. 114. *Macrophthalmus latipes*; A. whole animal, B. outside of hand.

Length of only specimen (a male): 5 mm. Breadth: 8 mm. Colour in spirit, white. In the flattened shape of its last pair of legs, this species recalls the Portunid genus *Podophthalmus*, already curiously like *Macrophthalmus* in the length of its eyestalks and its broad body.

Dredged from 36 *f.* South Nilandu Atoll.

Family **Palicidae.** Genus *Palicus* Philippi, 1838.

15. *Palicus jukesi* (White), 1847. Alcock, VI. p. 451.

According to Alcock, "the Indian species of *Palicus* live among coral shingle at a depth of from 10 to 40 fathoms, where their mottled coloration and granular rugose carapace afford a good concealment." The majority of the specimens of this species taken by the expedition were dredged on a bottom which contained coral shingle, but several were obtained from foraminiferal mud, quite unlike and unmixed with coral shingle. The species was taken from 25 to 45 fathoms in Suvadiva, Haddumati, South Nilandu, and Kolumadulu Atolls.

VI. THE SAND CRABS (OXYSTOMATA).

The morphological feature by which the Oxystomata are distinguished from other crabs is, at the same time, an indication of their most marked binomic peculiarity. This feature is to be found in the shape of the mouth and foot-jaws. The epistome is small or wanting, and the endostome is lengthened forwards, so that it is of a triangular shape. The channels for the outward stream from the gill-chamber, running on this endostome, are covered in by the long, leaf-like endopodites of the first pair of maxillipeds (*A* Fig. 110), and in this way are prolonged as closed tubes to the front of the body. The whole apparatus is neither more nor less than an adaptation to breathing under the special circumstances that present themselves in the sand-beds which form the characteristic habitat of the group.

The Oxystomata are singularly unanimous in their habits. Nearly all of them are crabs whose strength is to sit still, trusting to concealment rather than to agility or offensive tactics for protection against predaceous animals. Most of them find their concealment in the sand, where they lie buried with only the eyes exposed, and can often only be detected by the little whirlpool which they make in breathing. In such circumstances the advantage of having the breathing channels carried right up to the surface of the sand is obvious, and we have seen how this is done in the case of the outgoing stream. The incoming stream is ordered differently in different families. The Calappidae[1] (Pl. XXII. fig. 6) draw in water, like many other crabs, down a passage formed, so to speak, by "holding the hands against the breast," and so into the gill-chamber through an opening in front of the chelipeds, guarded by the wide base of the epipodites of the third pair of maxillipeds. But their hands (chelae) are peculiarly shaped for this purpose, being very broad and flat, and usually having a toothed crest, which is held against the forepart of the body. Through

[1] *Key to the families of the Oxystomata.*

I. Body of the shape usual in crabs. Abdomen hidden under thorax. Antennae small. Legs normal in position.

  A. Afferent openings to gill-chambers lie in front of first pair of legs (chelipeds). Gills 9 on each side. Male openings coxal. *Calappidae.*

  B. Afferent openings to gill-chambers lie on either side of the mouth at the base of the third maxillipeds. Gills less than 9 a side. Male openings sternal. *Leucosiidae.*

II. Body more or less abnormal in shape. Abdomen not hidden under thorax. Antennae large. Last one or two pairs of legs in a more dorsal position than the rest.

  A. Carapace short. Last two pairs of legs subprehensile, with hook-like end-joints. *Dorippidae.*

  B. Carapace long. Legs usually have the last two joints very broad. *Raninidae.*

Key to the subfamilies of the Calappidae.

I. Last three joints of 3rd maxilliped not hidden by the meropodite. Orbits not separated from the antennular sockets.

  A. Meropodite of 3rd maxilliped not elongate nor acute. Exopodite of same limb with flagellum. Legs not adapted for swimming. *Calappinae.*

  B. Meropodite of 3rd maxilliped elongate and acute. Exopodite of same limb without flagellum. Legs adapted for swimming. *Orithyinae.*

II. Last three joints of 3rd maxilliped hidden by the meropodite. Orbits more or less separated from the antennular sockets. [Exopodite of 3rd maxilliped with flagellum. Meropodite of same limb elongate and acute. Legs may be adapted for swimming or not.] *Matutinae.*

Key to the subfamilies of the Leucosiidae.

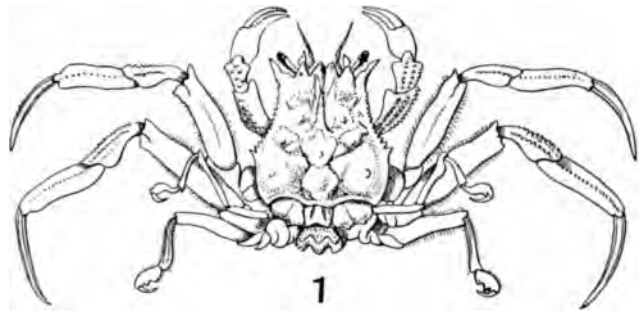
I. Meropodite of 3rd maxilliped more than half the length of the ischiopodite. Fingers stout, gradually narrowing from base to tip, usually shorter than the palm. *Leucosiinae.*

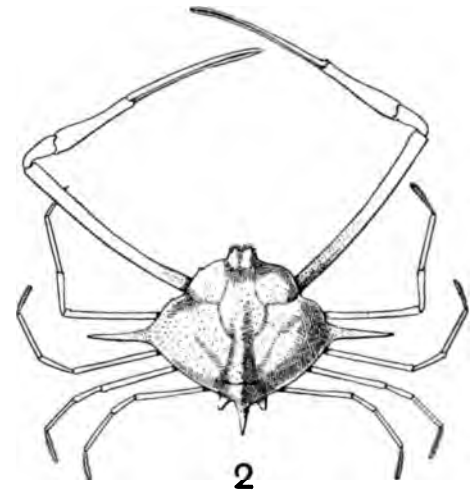
II. Meropodite of 3rd maxilliped never more than half the length of the ischiopodite. Fingers slender, of even width from the base to near the tip, usually longer than palm. *Iliinae.*

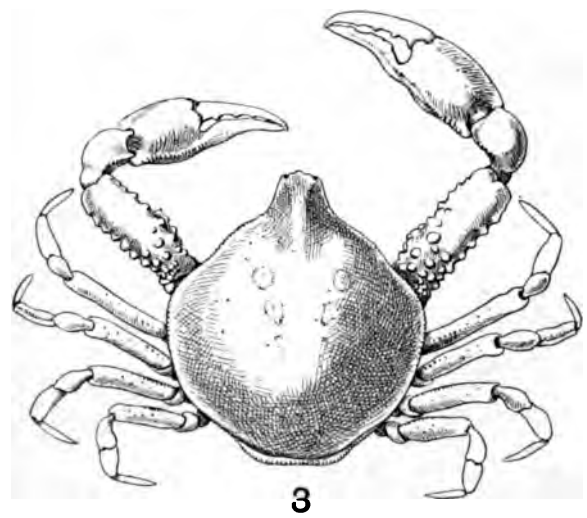
Key to the subfamilies of the Dorippidae.

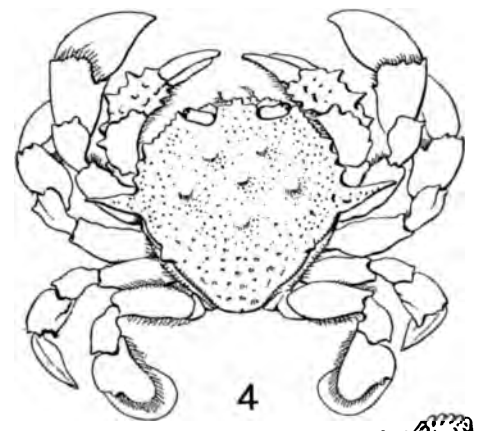
I. 3rd maxillipeds leave a good part of the mouth uncovered. Inward openings to the gills near the base of the chelipeds. *Dorippinae.*

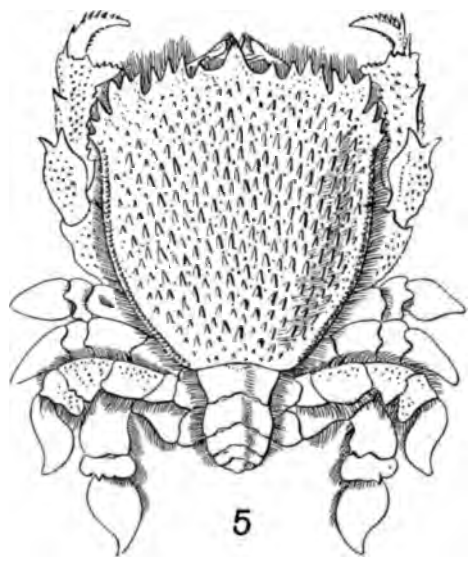
II. 3rd maxillipeds almost completely cover the mouth. Inward openings to the gills may or may not be near the base of the chelipeds. *Tymolinae.*

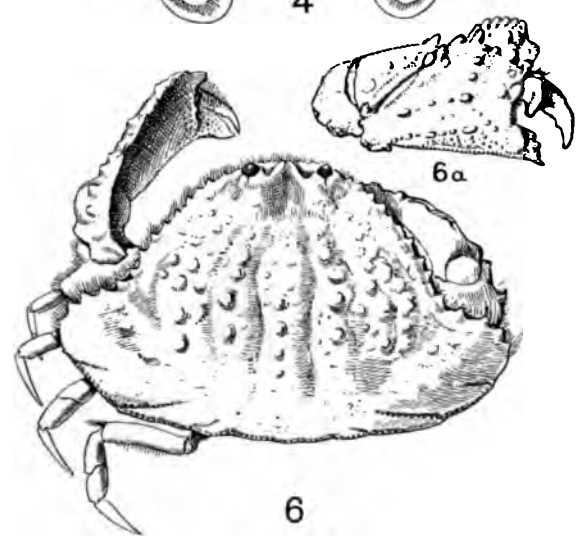












BORRADAILE——OXYSTOMATA.

To face p. 435.

the notches between the teeth water can enter, while at least the coarser sand-grains are kept out. *Matuta* (Pl. XXII. fig. 4) replaces these teeth, functionally, by a sieve of hairs. In the Leucosiidae, on the other hand, the openings for the ingoing stream are situated at the base of the maxillipeds of the third pair, and the water is led thither by a groove on the body, outside the efferent channel and parallel with it, covered by the third pair of maxillipeds. The Dorippidae (Pl. XXII. fig. 1) are probably divided in this respect, some breathing like the Leucosiidae, while others do not. In the Raninidae (Pl. XXII. fig. 5) a third method seems to be adopted. There are no obvious afferent openings in the forepart of the thorax, but spaces can clearly be seen between the hind edge of the carapace and the bases of the last pair of legs, and it is through these that the water probably enters.

Besides the conformation of the breathing organs just described we can trace other adaptations of the structure of Oxystomes to a sandy habitat. The comparatively simple egg- or pear-shaped body of some Leucosiidae is eminently suitable to a life spent buried in the sand, and the hard carapace found in most of these crabs is no doubt a last resource of the defenceless. *Calappa*, when seized, often draws up its legs under the broad shields formed by the overlapping edges of the carapace, thus seeming to sham death (Pl. XXII. fig. 6, right side). No doubt it is more difficult to dismember in this attitude, but it is quite possible that the action has no such special significance in this case, being instinctively adopted whenever the animal is moved against its will[1]. The colouring of many Calappidae is another feature in which they are adapted to their environment, being sand-like, and clearly protective.

Notwithstanding these generalisations, it is by no means likely that all Oxystomes hide in sand. *Dorippe* (Pl. XXII. fig. 1) conceals itself by holding a sponge or some other object over its back with its two hinder pairs of legs, which are dorsally placed and subchelate with hooked end-joints. Many of the Leucosiid genera show so strong a likeness to the Spider crabs (Oxyrhyncha) in their form of body and limbs (Fig. 117, and Pl. XXII. fig. 2) that they probably have a similar habit of weed-haunting, a view confirmed by the fact that several were taken in weed by the Expedition[2]. Another habitat is taken up by *Oreophorus* and *Tlos* (Fig. 115), which closely resemble water-worn coral pebbles, and live on shingle made up of such pebbles.

As a whole the Oxystomata are of distinctly sluggish habits, and this peculiarity reaches its height in the Leucosiidae. *Calappa* is perhaps somewhat more active. *Matuta* is not only a good swimmer, by means of paddle-like feet (Pl. XXII. fig. 4), but also an excellent digger, burying itself with wonderful rapidity in the sand. *Dorippe* is said to be able to run rapidly by means of its two pairs of very long walking-legs (Pl. XXII. fig. 1). And, lastly, the

EXPLANATION OF PLATE XXII.

FIG. 1. *Dorippe dorsipes.* FIG. 2. *Arcania quinquespinosa.* FIG. 3. *Leucosia marmorea.* FIG. 4. *Matuta banksi.* FIG. 5. *Ranina serrata.* FIG. 6. *Calappa hepatica*, legs on right side withdrawn under the shield. 6 *a*, outside of hand, showing crest. The figures are not drawn to one scale.

[1] *Calappa* is generally to be found in spots where deep sand is freely exposed to currents or wave motion, and in this compact form would probably undergo rolling about on a soft bottom without much injury.

[2] In considering the habitat of Oxystomes, as of other crabs, it should always be remembered that actual observation in shallow water is far more convincing proof than dredging on any particular bottom. For instance, a large crab dredged on a bottom of coral blocks may fairly be concluded not to be a sand-haunting one, but a small species may well make use of the hollows in the blocks, often as large as a man's fist, which are found to be filled with sand, and may have been dislodged in the dredge; and, again, the presence of weed or coral in a dredging always opens the possibility that some of the crabs found free may have belonged to them.

Raninidae are probably swimming sand-crabs, somewhat like *Matuta* in habits, as they are in the shape of the legs, and moving with jerks like the Galatheidae.

Judging from the contents of their stomachs, de Haan came to the conclusion that *Calappa*, *Matuta* and *Dorippe* feed on other crabs, *Leucosia* on prawns, and *Ranina* on fish and starfish. The following systematic list includes the forms taken by the expedition. All those not now described for the first time are of Indian or Indo-pacific distribution.

Family **Calappidae.**

Subfamily **Calappinae.** Genus *Calappa* Fabr., 1798.

1. *Calappa hepatica* (Linn.), 1764. Alcock, II. p. 142. (Pl. XXII. fig. 6.)

Taken at Hulule, Male Atoll and in Minikoi lagoon down to 5 fathoms.

2. *Calappa gallus* (Hbst.), 1803. Alcock, II. p. 146.

Dredged in Felidu, Haddumati and Suvadiva Atolls in 25—43 fathoms.

3. *Calappa depressa* Miers, 1886.

Miers, Challenger Brachyura, p. 287, Pl. XXIII. Fig. 2 (1886).

Dredged in Suvadiva Atoll in 43 fathoms.

4. *Calappa pustulosa* Alc., 1896, var. See Alcock, II. p. 147.

The specimens differ from the type in that: (1) the shields at the sides of the carapace are better developed, resembling those of *C. depressa* Miers; (2) the endostomial septum is complete in its hinder half and hollowed out in its anterior half only; (3) the whole antero-lateral edge is toothed (as in Alcock's figure. In his description he says that the anterior half is smooth). The name *clypeata* would be a suitable one to apply to this variety.

Dredged in Haddumati and Mulaku Atolls, in 30—39 fathoms.

Genus *Cryptosoma* Brullé, 1837.

5. *Cryptosoma granulosum* (de Haan), 1835. Alcock, II. p. 182.

Dredged in Suvadiva and South Nilandu Atolls, in 30—43 fathoms.

Subfamily **Matutinae.** Genus *Matuta* Fabr., 1798.

6. *Matuta banksi* Leach 1817. Alcock, II. p. 158. (Pl. XXII. fig. 4.)

Taken in Hulule, Male Atoll.

Family **Leucosiidae.**

Subfamily **Leucosiinae.** Genus *Oreophorus* Rüppell, 1830.

7. *Oreophorus reticulatus* Ad. and Wh., 1850. Alcock, II. p. 174.

Besides a full-grown male, there is in the collection a very small one which closely resembles the adult, and is not at all like the specimen figured by Adams and White as the young of this species ["Samarang" Crustacea, Pl. VI. Fig. 2].

Dredged in Kolumadulu and Fadifolu Atolls in 38 and 23 fathoms.

Genus *Tlos* Ad. and Wh., 1850.

8. *Tlos latus* n. sp. (Fig. 115).

Diagnosis: "A Tlos with the carapace broad and finely granulated all over, roughened by small pits and minute linear grooves among the granules; in the hinder part a mound, consisting of two large humps, one on each side of the cardiac region, and the latter region itself somewhat swollen, and connected with the front by a broad ridge, on each side of which is a deep pit; the front well developed, notched at the tip, not quite hiding the eyes; the anterolateral edge with one peak, the posterolateral irregular; the chelipeds about a third longer than the carapace in the female, irregularly nodular all over; the walking-legs short and nodular."

Length: 6 mm. Breadth: 9 mm. Colour in spirit, white.

Taken at Hulule, Male Atoll, and dredged in 35 fathoms in North Male Atoll.

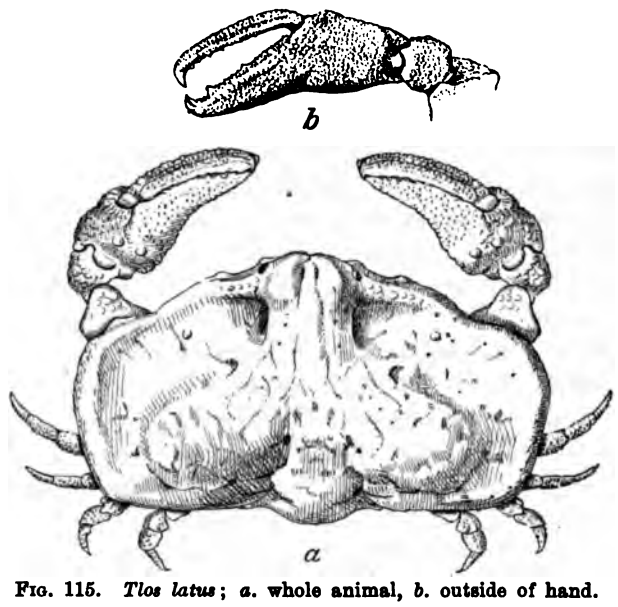


FIG. 115. *Tlos latus*; *a*. whole animal, *b*. outside of hand.

Genus *Ebalia* Leach, 1817.

9. *Ebalia erosa* (A. M.-Edw.), 1873. Alcock, II. p. 189.

Taken in Minikoi lagoon down to 9 fathoms and in Fadifolu Atoll in 22 fathoms.

10. *Ebalia maldivensis* n. sp. (Fig. 116).

Diagnosis: "An *Ebalia* with the carapace somewhat broader than long; the front prominent, rather deeply bilobed; the anterolateral edge with three projections, of which the hindermost is the smallest; the middle region of the carapace raised above the rest, bearing a large mound in the hinder part and a horseshoe of 8 smaller mounds in front, the smaller mounds varying greatly in distinctness in different specimens; the hind edge evenly arched; the body and limbs granular all over; the chelipeds of simple shape, without thorns or teeth, the fingers slender, grooved, as long as the somewhat swollen palm."

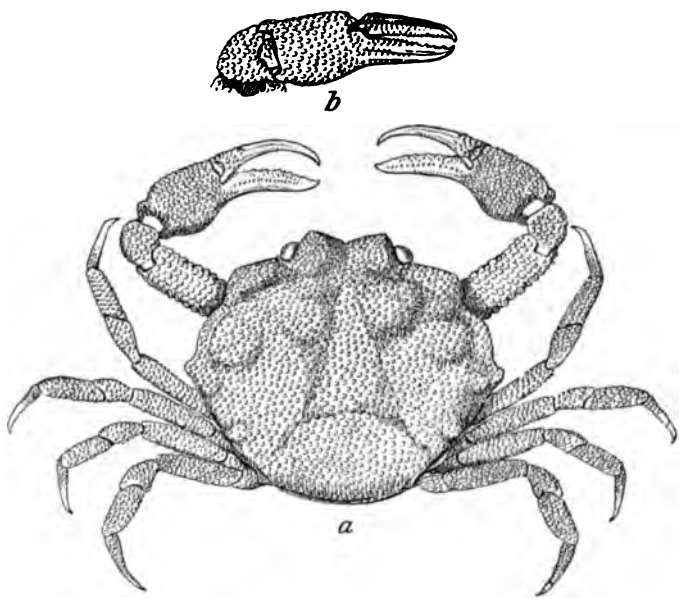


FIG. 116. *Ebalia maldivensis*; *a*. whole animal, *b*. outside of hand.

Length: 4·5 mm. Breadth: 5 mm. Colour in spirit, white, tinged in places with yellow.

Dredged in Suvadiva and Fadifolu Atolls in 43 and 23 fathoms.

Genus *Leucosilia* Bell, 1855.

11. *Leucosilia maldivensis* n. sp. (Fig. 117).

Diagnosis: "A *Leucosilia* with the carapace subcircular, covered with flattened granules which in the branchial regions pass into minute, flat-topped spines; the front short, barely hiding the epistome; a large hollow in the carapace on each side just behind the front and a ridge separating these hollows and running back to the gastric region, where it bears 5 knobs, 2 knobs one behind another on the cardiac region, and a blunt knob at each end of the hind margin; the chelipeds about ½ as long again as the carapace, granular, the granules being smallest on the hands, the fingers longer than the palms, furrowed, slender, and set with slender teeth of various sizes; the walking-legs short and slender, with long end-joints."

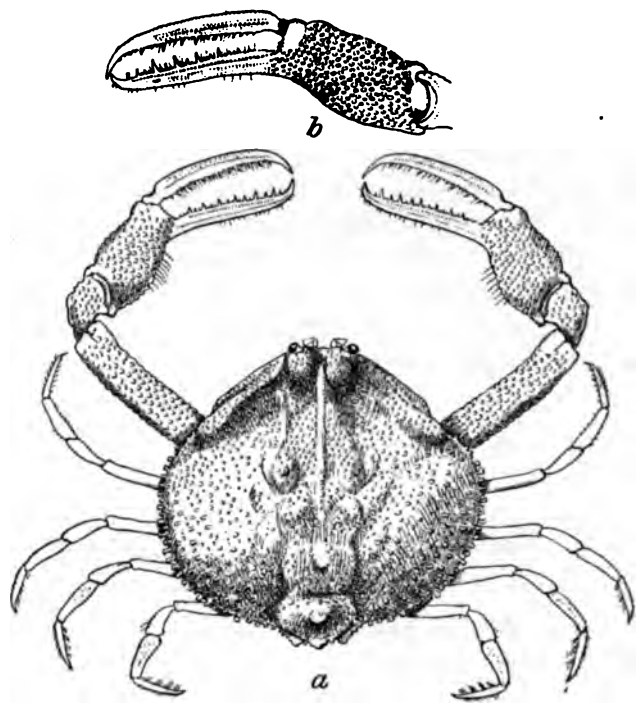


FIG. 117. *Leucosilia maldivensis*; *a*. whole animal, *b*. outside of hand.

Length: 12 mm. Breadth: 11 mm. Colour in spirit, white.

Dredged in Suvadiva Atoll, in 43 fathoms.

Genus *Myra* Leach, 1817.

12. *Myra brevimana* Alc., 1896. Alcock, II. p. 206.

Dredged in Kolumadulu and South Nilandu Atolls, in 35 and 36 fathoms.

13. *Myra darnleyensis* Hasw., 1879. Alcock, II. p. 207.

Dredged in Suvadiva, South Nilandu and Mulaku Atolls in 28—43 fathoms.

14. *Myra intermedia* n. sp.

A specimen of a new form of *Myra* in the collection shows a combination of characters which tend to unite the species *M. fugax* (Fabr.), *M. affinis* Bell, and *M. brevimanus* Alc.

The following are the diagnostic features of the new form: (1) Carapace rather sparsely covered with granules, which are smaller than in *M. brevimana* except on the intestinal region and the base of the large hinder spine, where they are coarse and close set. (2) A keel is present in the middle of the back and is more closely granular than the field on either side of it. (3) The tooth on the hinder part of the upper of the two lines which define the hepatic facet is almost lost. (4) The front hardly projects to the same level as the

outer tooth of the breathing channel; it is widely, but not very deeply, notched. (5) All the three spines at the hinder end are sharp. The middle one is much the longest and is somewhat upcurved at the tip, which is free from granules. (6) There is no tooth at the end of the long segment of the male abdomen. (7) The length of the male cheliped : length of carapace (without spine) :: 5 : 3. The palm is short, and the moveable finger almost exactly equals the outer edge of the palm in length.

The specimen is a male 15 mm. long without the spine and is probably full-grown. The colour in spirit is dirty white. It was dredged in 30 fathoms in Mulaku Atoll and probably taken from a sponge.

Genus *Leucosia* Fabr., 1798.

15. *Leucosia marmorea* Bell, 1858. Alcock, II. p. 221. (Pl. XXII. fig. 3.)

Dredged in Felidu and Mulaku Atolls in 25 and 40 fathoms.

16. *Leucosia* sp. aff. *pallida* Bell, 1855. See Alcock, II. p. 222.

A damaged male specimen of a *Leucosia* from Hulule resembles *L. pallida* in the shape of the carapace, but differs in that: (1) the front has the middle tooth broad and slightly emarginate at the tip. (2) The crenulation of the anterolateral edge is almost obsolete. (3) The outer limb of the V-shaped thoracic hollow is obsolete.

Genus *Pseudophilyra* Miers, 1879.

17. *Pseudophilyra pusilla* Hend., 1893. Alcock, II. p. 281.

The markings on the carapace are irregular and do not agree with Alcock's description. In particular the brown band across the tip of the front is wanting. The palms are somewhat longer and flatter than in Henderson's figure [*Tr. Linn. Soc.* (2) v. *Zool.*].

Dredged in Minikoi, South Nilandu and Suvadiva Atolls in from 2 to 43 fathoms.

Subfamily **Iliinae.** Genus *Nursilia* Bell, 1855.

18. *Nursilia dentata* Bell, 1855. Alcock, II. p. 260.

Dredged in South Nilandu, Kolumadulu, Suvadiva and Mulaku Atolls in various depths down to 40 fathoms.

Genus *Arcania* Leach 1817.

19. *Arcania tuberculata* Bell, 1855. Alcock, II. p. 268.

Dredged in South Nilandu Atoll in 30 fathoms.

20. *Arcania quinquespinosa* Alc. and And., 1894. Alcock, II. p. 266. (Pl. XXII. fig. 2.)

Dredged in Haddumati, Kolumadulu and Suvadiva Atolls in various depths down to 44 fathoms.

Family **Dorippidae.** Genus *Dorippe* Fabr., 1798.

21. *Dorippe dorsipes* (Linn.), 1764. Alcock, II. p. 277. (Pl. XXII. fig. 1.)

The specimen carried a sponge when taken. It was dredged in Haddumati Atoll in 40 fathoms.

VII. THE BARNACLES (CIRRIPEDIA).

Seeing that the Barnacles are sessile animals, and need to attach themselves to a firm holdfast, it might be expected that they would be numerous and characteristic inhabitants of coral reefs, which give so many opportunities of settlement on fixed bodies, under conditions so diverse both biologically and physically. But, curiously enough, as Darwin has remarked[1], coral reefs are, for some reason, not favourable to them. Yet a number of species may be taken there, and some are even characteristic and specially modified for the habitat. Among these may be included the *Lithotryas* which bore into coral rock, those species of *Pyrgoma* which live imbedded in reef corals, and several of the *allium*-group of *Balanus*, besides common species such as *B. tintinnabulum* and *B. amphitrite*. Of course those which live on animals such as sea-snakes or turtles and on floating objects as cuttle-bones or pieces of wood, are also found.

The collection contains 16 species, including members of all the groups mentioned above. Of these species two are new. Most of the others have already been recorded from some part of the Indo-Pacific region, but one form can only be classed as a variety of the West Indian *Lithotrya dorsalis*, and another, whose locality has hitherto been unknown, was formerly supposed to be (and still may be) West Indian.

Family **Lepadidae.**

Genus *Lepas* Linn., 1758.

1. *Lepas ansifera* Linn., 1767. Darwin, I. p. 81[1].

Taken on floating objects in various localities throughout the Archipelagoes, a number of the younger individuals being on cuttle-bones.

Genus *Dichelaspis* Darw., 1851.

2. *Dichelaspis warwicki* (Gray), 1825. Darwin, I. p. 120.

The specimens differ from that figured by Darwin in that the upper end of the occludent segment of the scutum is considerably wider than the base of this segment, leaving only a narrow strip of soft skin between itself and the basal segment. But Darwin says that this segment may be wider in the upper part. The plate at the base of the carina is an independent ossicle, joined by a suture to the true keel.

Taken in Suvadiva Atoll.

3. ? *Dichelaspis grayi* Darw., 1851. Darwin, I. p. 123.

A specimen which I believe to belong either to this species or to *D. pellucida* Darw., 1851, is attached to a sea-snake (*Hydrus platurus*) taken by the expedition in the Maldives.

Unfortunately, the shells are so badly preserved, owing to their having been kept in formalin, that it is impossible to be certain of the species. It is the habit of both species to live on sea-snakes.

[1] All the references to Darwin's work in this paper are to his "Monograph of the Cirripedia," London, 1851–4.

Genus *Conchoderma* Olfers, 1814.

4. *Conchoderma hunteri* Darw., 1851. Darwin, I. p. 153.

Hoek ("Challenger" Cirripedes) regards this form as a variety of *C. virgata* (Spengler), 1790, but the latter has not been found on sea-snakes, while *C. hunteri* appears to have that habitat, Darwin's specimen and the present both so occurring. The only others recorded (Stebbing, Willey's *Zool. Results*, vol. v. p. 676) made the pardonable mistake of attaching themselves to submarine cables. This fact lends support to the presumption that the species are distinct.

Genus *Lithotrya* Sowerby, 1822.

5. *Lithotrya dorsalis* (Ellis), 1786. Darwin, I. p. 351.

I am unable to regard the Maldive specimens of this genus otherwise than as belonging to varieties of this West Indian species. Two forms may be recognised, the type (var. A) not being present.

B. Var. *maldivensis* n.

Differs from the type in the following points: (1) There is a very faint ridge within the carina. (2) The caudal appendages are rather less than half as long again as the last pedicel. (3) There is a shallow notch on the maxilla of the right side, though none on the left. (4) The tergal edge of the scutum is slightly concave. (5) The scuta are longer than in *L. dorsalis*. (6) The *carina* is shorter.

These latter two features, however, may well be due to a difference in the manner in which the specimens have become worn by the sea.

C. Var. *rugata* n.

Differs from the preceding variety in the following points: (1) The carina has a fairly strong ridge. (2) The caudal appendages are only very slightly longer than the pedicel of the last limb. (3) The rostrum is bordered by 6 scales instead of 3.

This species lives on the under side of overhanging coral rocks and is always so placed that its capitulum is at the opening of the hole. I am at a loss to understand how some of Darwin's specimens came to be reversed. For some remarks on its importance in the disintegration of coral rock, see Mr Gardiner's Paper in Part III. of this publication (p. 337).

Family **Balanidae.** Genus *Balanus* Da Costa, 1778.

6. *Balanus tintinnabulum* (Linn.), 1758. Darwin, II. p. 194.

The specimens, which were taken in various localities, are all small and belong to the var. *communis*.

7. *Balanus amphitrite* Darw., 1854. Darwin, II. p. 240.

The specimens are coloured pink and much resemble *B. tintinnabulum*. They are small and have given me much trouble, but I have finally placed them here on account of the undoubted absence of pores from the radii, and because the mandibles agree best with Darwin's description for this species. They were taken in Fadifolu Atoll.

8. *Balanus quadrivittatus* Darw., 1854. Darwin, II. p. 284.

Taken in Miladumadulu Atoll.

9. ? *Balanus terebratus* Darw., 1854. Darwin, II. p. 288.

I am unable to find in my specimens the rows of holes between the ridges of the basis as described by Darwin. Possibly the species is distinct. The scuta and terga, which were wanting in Darwin's specimens, have the following characters in mine:

Scuta. Shape that of a right-angled triangle with convex base. Growth ridges on the outside curved. Adductor ridge strong and articular moderate.

Terga. Spur very short and fairly broad. Growth ridges on the outside curved. Spur groove wide, shallow. Apical tooth present, but broken in the specimen.

Taken on the reef at Naifaro, Fadifolu Atoll.

10. *Balanus maldivensis* n. sp. (Fig. 118).

Diagnosis: "A *Balanus* with solid walls, the basis, radii and parietes being without canals, though indications of these are seen in the parietes when the latter are broken; the opening rhomboidal, and toothed owing to the projection of the tips of the parietes, the walls gnarled and often ringed, but not regularly ribbed; the scutum of simple, obtuse-angled triangular shape, with slight articular and no adductor ridge; the tergum very broad with a rounded tip, a short, broad spur, which is also rounded at the end, a sharp tooth at the end of the scutal edge next the spur, and a sharp, though not very deep, spur groove; the outside of both scutum and tergum moderately strongly ridged; the mandible with seven teeth, which grow smaller in succession from above downwards, and of which numbers 1—5 are blunt and often subdivided, while 6 and 7 are sharp, a row of stiff bristles along the lower edge and the sides and upper edge hairy; and the edge of the maxilla almost straight, without notch or projection."

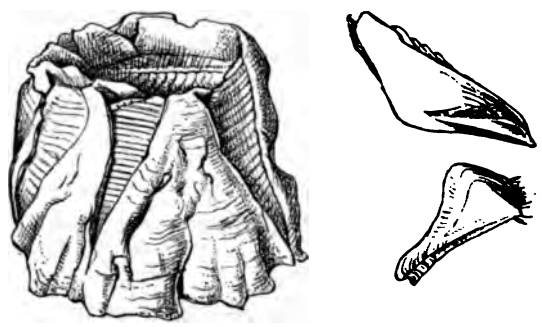


Fig. 118. *Balanus maldivensis*; whole animal, with scutum and tergum detached and seen from the inside.

Length of longest specimen: 7 mm. Height: 6 mm.

Taken in S. Nilandu Atoll, on a twig of wood.

The peculiarities of the shell of this species would appear to necessitate the founding for it of a new section [H] of the genus, with the characters: "All parts of the shell present, heavy, and without pores."

Genus *Acasta* Leach, 1817.

11. *Acasta sulcata* Lam., 1818. Darwin, II. p. 310.

Dredged in two fathoms in Fadifolu Atoll.

Genus *Pyrgoma* Leach, 1817.

12. *Pyrgoma cancellatum* Leach, 1824. Darwin, II. p. 362.

Darwin did not know from what locality his specimens of this species had been brought, but supposed it to be the West Indies. The present specimens were dredged in Suvadiva Atoll in 26 fathoms.

13. *Pyrgoma grande* (Sowerby), 1839. Darwin, II. p. 365.

This species lives inside the polyps of *Euphyllia*. The outside of the basal cup of the cirripede often shows septa formed by the polyp, so that it would appear that the soft parts of the polyp adapt themselves to the invasion by growing over the foreign body. [The same or another species lives commonly in the Maldives on *Galaxea*. ED.]

Darwin reports *P. grande* from "two sorts of corals," and it is evident from his figure that in at least one of these the same relation between the barnacle and the coral is found as in our specimens.

14. *Pyrgoma madreporae* n. sp. (Fig. 119).

Diagnosis: "A *Pyrgoma* with the shell flat, oval, the opening keyhole-shaped; the ridges well developed, alternately long and short, rather wide apart, about 11 in a quadrant, projecting somewhat at their outer ends; basal cup very strongly ribbed inside; scutum of simple, triangular shape, with a rounded basal edge and a well-developed adductor ridge; tergum also triangular, with a short spur; cirri delicate, the series growing longer from before backwards; mandible with 5 teeth, exclusive of the lower angle, which bears a number of bristles, the teeth growing smaller from above downwards."

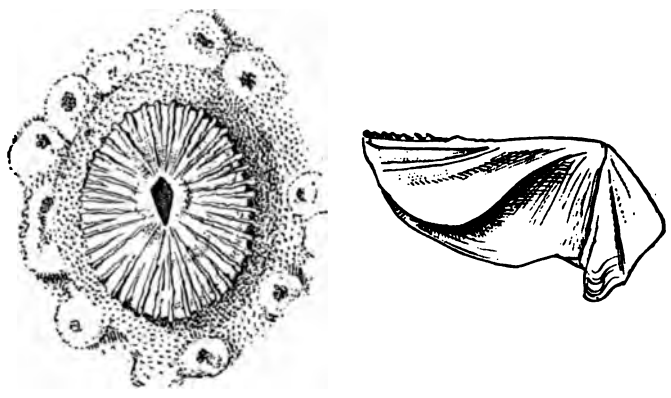


FIG. 119. *Pyrgoma madreporae*; whole animal imbedded in coral, with detached scutum and tergum seen from the inside.

Breadth of largest specimen: 8 mm. Colour in spirit, white.

Found in a *Madrepora* at Hulule, Male Atoll.

Genus *Chelonobia* Leach, 1817.

15. *Chelonobia testudinaria* (Linn.), 1758. Darwin, II. p. 392.

Two specimens were taken on the carapace of the turtle *Chelone midas* in Minikoi.

16. *Chelonobia caretta* (Spengler), 1790. Darwin, II. p. 394.

Several specimens were found in the skin on the legs of the turtle *Chelone imbricata* in Minikoi.

MARINE CRUSTACEANS.

VIII. STOMATOPODA, WITH AN ACCOUNT OF THE VARIETIES OF GONODACTYLUS CHIRAGRA.

By W. F. Lanchester, M.A., *King's College, Cambridge.*

(With Plate XXIII.)

I. ADULT FORMS.

The adults in this collection all belong, with the exception of two specimens of *Pseudosquilla ciliata*, to the genus *Gonodactylus*; moreover they should be included in a single species of that genus, namely, the world-wide *G. chiragra*. On first being sorted out these *Gonodactylus* fell fairly readily into three groups, (*a*) representing the *G. chiragra* of most authors (not of Fabricius, to which point I shall return later), (*b*) representing the *G. glabrous* of Brooks, and (*c*) seven specimens representing the *G. spinosus* of Bigelow. Closer examination, however, revealed in each of the first two groups a considerable amount of variation, chiefly in respect to the characters of the 6th abdominal segment and the telson, that is to those which more particularly distinguish the two forms: and in seeking to group these variable forms I was led insensibly to the conviction that no hard-and-fast line could be drawn between the two species, and that Brooks was right in his estimate, which I did not see till later, that "future discoveries may reveal so many transitional forms that the sharp lines between the species" (including a third, the *G. graphurus* of Miers) "will break down" (Chall. *Stom.* p. 64). The third group, that of *G. spinosus*, numbers but few specimens, and therefore presents little evidence of variation.

The great preponderance of this species in the Maldives and Laccadives is a striking fact, for which, unfortunately, no explanation can at present be forthcoming. A partial explanation lies in the fact that these forms are found on the surface of the reefs, or sea-bottom, whereas the genus *Squilla*, so conspicuous by its absence in this region, and yet one of the commonest forms of Stomatopods in the Indo-Malaysian region, lives in burrows in the sand or mud, from which it is a matter of some difficulty to dig it out even when the burrows are uncovered at low water, while it renders it unlikely that many will fall victims to the dredge. But this is only the smallest part of the question; for Mr Stanley Gardiner has assured me that he used every effort to obtain *Squilla* from holes at low water, so that we may feel certain that, had the genus existed in any quantity at all,

there would have been a few specimens at least in the collection. And without going so far as to say that the genus *Squilla* is quite unrepresented in this locality, it is yet sufficiently obvious that, for some reason, the conditions are more suitable generally to *Gonodactylus chiragra*. The bathymetric distribution, so far as this collection is concerned, ranges from littoral to 44 *f.* (fathoms).

1. *Gonodactylus chiragra* (Fabr.) Herbst.

Fabricius, *Spec. Insect.* p. 515 (1781), *Mant. Insect.* p. 334 (1787), *Ent. Syst.* III. 1, p. 513 (1793), and *Ent. Syst. Suppl.* p. 417 (1798): Herbst, *Cancer (mantis) chiragra, Krab. u. Krebs.* II. p. 100, Pl. XXXIV. Fig. 2 (1796): M.-Edw., *Hist. Nat. Crust.* II. p. 528 (1837): Dana, *U.S. Expl. Exp. Crust.* p. 623, Pl. XLI. Fig. 5 (1852): Heller, *Novara-Reise, Crust.* p. 126 (1865): v. Martens, *Arch. f. Naturg.* 38, p. 147 (1872): Miers, *Ann. Mag. Nat. Hist.* (5) v. p. 118, 1880: Brooks, '*Challenger*' *Stomatopoda*, p. 56 (1886), *G. glabrous, id.* p. 62, Pl. XIV. Fig. 5, Pl. XV. Fig. 7: Henderson, *Trans. Linn. Soc. Zool.* (2) v. p. 454 (1893): *G. glaber, id. loc. cit.*: Bigelow, *Proc. U.S. Nat. Mus.* XVII. p. 494 (1894): *G. spinosus, id. l.c.* p. 493: Hansen, *G. oerstedii, Plankton-Exp. Isop. Cumac. u. Stomatop.* p. 65 (footnote) (1895): Borradaile, *Proc. Zool. Soc.*, p. 32, Pl. VI. Fig. 8 (1898): *G. espinosus, id.* p. 35, Pl. V. Fig. 5: *id.* Willey's *Zool. Res.* Pt IV. p. 400 (1900): de Man, *Zool. Jahrb. Syst.* x. p. 694 (1898): Nobili, *G. festae, Boll. Mus. Zool. Torino*, XVI. p. 53 (sep. copy 1902).

The synonymy of this species is, at present, rather confused, owing, no doubt, to the considerable range of variation exhibited by it, and it is unfortunate, from one point of view, that Fabricius is not sufficiently detailed in his description of that part of the animal, viz. the 6th abdominal segment and the telson, which presents so much variation; the rest of his account is particularly clear and complete. This full description is to be found twice, once in the *Species Insectorum* (1781) and again, with but slight alteration, in the *Entomologia Systematica* (1793); in his other two works he refers to it only with a brief diagnosis. What he has to say about the hinder part of the animal is the same in both cases:— "Abdomen...decimo segmento lineis sex elevatis spinosis, ultimo lineis elevatis spinosis margineque postico spinis serrato." Now the latter part of this may signify one of two things. Either it may mean that the three carinae of the dorsal surface are "raised and spinous" while the posterior border is "serrated with spines" corresponding to the four or six *marginal* spines[1]; or it may be that the words 'lineis elevatis spinosis' refer to the four or six marginal spines with their forwardly-running carinae, while the spines with which the hinder border is serrated may be the numerous small spines between the marginals[2]. In the *Spec. Ins.* and the *Ent. Syst. Suppl.* Fabricius refers his species to the *Squilla arenaria marina* of Rumphius, and examination of Rumphius' plate renders it more likely that the second of the two alternatives is correct, since the dorsal carinae are not represented as spinous. Fabricius' type specimens do not, so far as I know, now exist; there are, at any rate, no examples of Stomatopods in the collection of his types at the Kiel Museum, as I am informed by Dr Immermann of that Museum, who very kindly examined the specimens preserved there for me. Accordingly it is quite impossible to decide which variety Fabricius was dealing with, though, as there is no doubt he had at least one of the varieties of this animal before him, there is no difficulty about retaining his specific name. I pass now to the consideration of the forms described by succeeding authors:—

[1] Corresponding to var. *smithii* or var. *glabrous*. [2] Corresponding to any variety of the species as a whole.

1796, Herbst. Figure very poor. Text:—"Das letzte Glied hat solcher Erhöhungen drey, und einen breiten, platten, Rand der durch Einschnitte *viermal* gezähnt ist." (Italics mine.) Corresponds with my variety F below.

1837, M.-Edwards. Text:—"Abdomen...son dernier article surmonté de six gros tubercules alongés et son dernier segment...portant *trois ou cinq* tubercules alongés *très arrondies*, et armé de dents marginales courtes, larges, et renflées." (Italics mine.) The presence of "three or five" tubercles on the telson is interesting as showing that Milne-Edwards had before him examples both of var. F mihi and var. *glabrous* Brooks (or var. *graphyrus* Miers) and yet did not distinguish them as species; in fact he adds, at the end of his description, and after giving a long list of localities to show the world-wide distribution of the species, "du moins je n'ai pu découvrir aucune particularité constante pour distinguer entre eux les individus venants de ces parages éloignés." The absence of any mention of the 'anchor,' and the fact of the ridges being very swollen (très arrondies) renders it probable, though not absolutely certain, that his forms with three ridges correspond with my var. F.

1852, Dana. The lateral marginal teeth and the anchor are not shown in the figure. Corresponds to var. F.

1865, Heller. A small specimen, 20 mm. long, badly preserved. Text:—"Das letzte Segment dreieckig, stark gewolbt, in der Mitte mit *einen scharf* Längskiele versehen, der nach rückwärts mit *einem kleinem Stachel* endet, nach beiden Seiten hin dachförmig, glatt; die Ränder jederseits mit drei Zähnen bewaffnet." (Italics mine.) The presence of only one ridge is due to the small size of the specimen, without doubt; although the lateral ridges are generally visible even in smaller specimens than Heller's, they are sometimes obscure (or possibly absent) in individuals of 20 mm., though this is not usual. The sharpness of the median keel, its termination in a spine, and the presence of lateral marginal teeth point to the specimen being a young var. *smithii*.

1872, von Martens. Pointed out evidence of considerable variation in the presence or absence of spines. It is not apparent which variety his specimens correspond to.

1880, Miers. In this his well-known work "On the Squillidae" Miers has given a full description of our species: the only points which concern us are in regard to the telson, which in his forms has three swollen spineless carinae, the middle one without an anchor and no lateral marginal teeth. For two reasons in particular I have chosen this as the type, firstly, because it is the form of Herbst who described the species shortly after Fabricius, and also the form of the great majority of authors after him; and secondly, because it is the form from which most of the varieties with which I shall deal appear to have taken their origin. Dr de Man in 1898 selected the spineless anchor-form as the type, but he gave no reason for so doing, and it is extremely improbable that Fabricius' types corresponded to this form at all: anyhow in the absence of evidence as to Fabricius' types we are justified in taking Herbst's form as the type of the species. The type then corresponds with my variety F.

1886, Brooks, and 1893, Henderson. Follow Miers. 1894, Bigelow. In his key to the species of *Gonodactylus* Bigelow makes it quite clear that his *G. chiragra* is identical with the type. 1898, de Man. His type form corresponds with my variety *incipiens b* = var. A. 1900, Borradaile. Has followed de Man. I have adhered to the system of lettering introduced by him, so that his var. A and mine correspond, as do the rest of the varieties lettered by him.

Turning now to the different varieties of *G. chiragra*, as now defined, afforded by this collection and the accounts of earlier authors, I must premise that I find it necessary to deal with them under three headings, the first two concerning those varieties which connect with each other by greater or lesser transitions of structure, the third concerning those which do not fall so readily into a transitional scheme. It will be easily understood that by the very nature of the case the exact definition of the different varieties must be a matter of considerable difficulty, that it would be open to any other observer, by a re-shuffling of the cards, so to speak, to form a scheme differing, in detailed arrangement, from the one now given, and that such a scheme cannot pretend as yet, while the material, and the information on this material, are still so comparatively limited, to represent with any certainty the *genetic history* of the forms in question.

First heading. I. Var. *tumidus* var. nov. Pl. XXIII. figs. 1 and 1 *a*.

This is that form of *G. chiragra* which has been taken by most carcinologists to be the type of the species, in which there are three much swollen carinae, without spines, on the telson, and no lateral marginal teeth. To this should be referred the examples described or figured by Herbst, Milne-Edwards (*partim*), Dana, von Martens, Miers, Brooks, Henderson, Bigelow, Borradaile. Although the absence of the lateral marginals is characteristic of this variety, yet sometimes traces of these teeth may be seen, as in the case of Fig. 1, and it is worth noting that the tooth is more prominent on the one side than the other; in a second specimen the teeth are absent, and in a third the rudiments of teeth are equal.

3 ♂♂, length 61·5, 48·5, and 44·5. Minikoi; with the following note:—"variegated green and white. The dark patches on the last thoracic segment and 5th abdominal segment are very characteristic; latter orange-red in centre." From the reef.

II. Forms connecting var. *tumidus* with III. var. *acutus*. Pl. XXIII. fig. 2.

The carinae are distinctly less swollen, especially the median. No lateral marginals.

1 ♂, length 42·5, and 2 ♀♀, 50 and 43, Minikoi. From the reef.

III. Var. *acutus* var. nov. Pl. XXIII. figs. 3 and 3 *a*.

The three carinae are now sharply defined, and the distal end of the median carina drops almost vertically so as to appear angular, rather than rounded and sloping as in var. *tumidus*. No lateral marginals.

3 ♀♀, length 38·5, 37, and 39, Minikoi, with the same note as that applying to the specimens of var. *tumidus*, and 2 ♀♀, length 62·5 and 15, Minikoi. From the reef.

IV. Var. *smithii* Pocock. Pl. XXIII. figs. 4 and 4 *a*.

Carinae sharp, the median with a well-defined terminal spine. Lateral marginal teeth present.

1 ♂, length 22, Hulule, Male Atoll, Maldives. From the reef.

To this form belongs a specimen referred by me to var. *smithii* Pocock in the *Proc. Zool. Soc. London*, 1900, p. 555; also three specimens referred by Borradaile to the same variety from Rotuma. In the latter's examples there are no signs of backwardly-directed carinae proceeding from the base of the spine of the median carina; in my two specimens, however, these can just be seen (cf. fig. 4), and this form clearly leads on to

V. Pl. XXIII. fig. 5 with which it may be included, and which differs from it only in the definite presence of carinae proceeding from the base of the spine, and forming an 'anchor.'

3 ♂♂, length 29, 30·5, and 18, and 3 ♀♀, 51·5, 36, and 27·5. Hulule, Male Atoll, Maldives. From the reef.

This is the type of var. *smithii* as figured by Pocock.

VI. Var. *segregatus* a. var. nov. Pl. XXIII. fig. 6.

This variety is very similar to var. *smithii*, but has the carinae slightly more swollen, with the spine not quite so prominent, and the flukes of the anchor separated from the base of the spine, and forming two low carinae extending not more than halfway along the sides of the median carina.

4 ♀♀, length 13, 12, 11, and 9, Goidu, Goifurfehendu Atoll. From the reef; 1 ♂, 9·5, South Male Atoll, 25 *f.*; 1 ♀, 17, Minikoi, from the reef; 1 ♀, 7·5, Hulule, Male Atoll, from the reef; and 1 ♀, 12, South Nilandu Atoll, 25 *f.*

It will be seen that the representatives, in this collection, of this variety are all of comparatively small size, and the imperfection of the anchor might be due to this fact. But I have also seen similar examples, in the collection of the Natural History Museum at S. Kensington, from the Macclesfield Bank, eight in number, and ranging from 20 to 30 mm. in length; while some specimens from the 'Skeat' collection of Crustacea, which differ only in the absence of the spine on the median carina, but agree in the separation of the flukes of the anchor, and to which I shall refer later, range from 20 to 28 mm. in length.

VII. Var. *segregatus* b. Pl. XXIII. figs. 7 and 7 *a*.

Some small specimens, quite similar to var. *segregatus*, but the separated flukes of the anchor, or sometimes one only on one side, bear a small spine at their distal extremity; this I should include under var. *segregatus*.

1 ♀, length 18·5, North Male Atoll, 27—35 *f.*; and 1 ♂, 17·5, and 4 ♀♀, 14·5, 13, 12, and 7·5, South Nilandu Atoll, 19 *f.*

VIII. Var. *glabrous* Brooks. Pl. XXIII. figs. 8, 9 and 15.

This includes the *G. glabrous* of Brooks and *G. glaber* of later authors, together with some additional forms to which reference will be made below (p. 451). On this variety it will be necessary to make some preliminary remarks before attempting any description of it, and in these remarks I shall deal with the variety as a whole, although I have, from the point of view of the transition scheme, separated off a portion of it under the second heading as in the case of var. *segregatus*. Now in dealing with the specimens of this variety in the collection I found that, though I could distinguish two extremes of structural form readily enough, yet I could not separate the individuals into two groups corresponding with these extremes, the intermediates between the two being relatively numerous and presenting all grades of slight structural differentiation. And, in spite of the smallness of the number before us, it seems to me legitimate to infer, from the evidence as it stands, that we have here a case of a Continuous (or Normal) Variation; and in fact that, different though the two extremes are structurally, yet they cannot be considered as varieties in the strict sense of the word, in face of the intermediates which exist between them. I must not, however, be taken to underrate the danger of arguing from such a small number of specimens; the facts

in the present instance do not prove, they only point to, the presence of Continuous Variation: but I do maintain (and the more I have examined the specimens, the more has my conviction been strengthened) that such evidence as there is compels us, for the present at any rate, to recognise that the Variation within the variety is Continuous. The actual proof of this point must depend on the examination of a very large number of specimens; and it seems to me that, when this examination has been made, it will be found to confirm the opinion suggested by the more slender evidence at present at our command. Assuming then that we have here Continuous Variation, or considering any other case in which we know we have similar variation, it seems desirable that the two extremes in such a case which, if the variation were Discontinuous, would be designated as *varieties*, should also be denoted by some analogous expression. For purposes of general discussion, of course, a precise word is not absolutely necessary, some such expression as 'the two extremes' expressing the point at issue sufficiently clearly; and it is equally possible to distinguish the two extremes as 'high' and 'low' respectively (cf. Bateson's *Materials*, pp. 39—40). But the practical convenience of the systematist often requires a definite symbol by which to designate a form he is describing; it would not be enough, for instance, that he should designate a specimen var. *glabrous* without specifying whether it is one or other extreme of that variety, or one of the intermediates. Of course it is not possible to sum up any given intermediate in a word, but the extremes give us fixed points on which we may rely. I propose, therefore, to use the word '**term**' to express the extremes of structural type manifested in a Continuous Variation, and for purposes of systematy, it is only necessary to qualify the word by the addition of, say, an alphabetical letter to distinguish the one term from the other. For the word itself I would point out that it is brief, it is Latin in origin, that in its primary meaning it expresses what it is wished to express, namely the existence of "ends" to a series, and lastly but not leastly it is quite neutral, suggesting no more than it is meant to suggest. The expression 'end-form' is excluded by reason of the special meaning recently attached to the word 'form'; the word 'extreme' on the other hand is of so much use for general purposes that it would only make confusion to give it a special meaning (as indeed has happened now in the case of the word 'form'). 'End-term' suggested itself, but is, after all, tautologous. The words 'high' and 'low' have been already used by Mr Bateson in a special sense, applying to the ends of a Discontinuous series in the case of the males only of a species; moreover they imply degree of variation.

Assuming, then, the use of this word, two points call for special comment. Firstly, it is plain that the use of the word can be of no help in the cases where it is an intermediate that is being referred to, and as by the nature of the case, the intermediates are more numerous than the terms, it may be objected that the word will have but a very limited value. This is true, but the value, limited though it be, seems to me a real value. The fact that we cannot express by a word the differences between the intermediates does not alter the fact that we can so express the often great structural differences between the two extremes. Were two genera to be found to be united by a continuous series of intermediates the series would form a single genus and species, but it would none the less be convenient to designate the extremes, with their great structural differences, by some special word, even though we could not do the same in the case of any given intermediate which also differed greatly from one of the extremes.

Secondly, it is always possible that, though in a given series two extremes may be distinguished as 'term *a*' and 'term *b*,' later research may show one or the other not to be

the real term. In this case, however, I see no difficulty in transferring the term, whether '*a*' or '*b*,' to its proper position, the original term falling then into its proper place as an intermediate.

Turning now to the present instance, I should describe the variety as follows:—

var. *glabrous* Brooks.

Five dorsal carinae on the telson, all of which are well-developed; these carinae are either sharp or tumid, and the middle three may or may not terminate in spines. This variety is subdivided into

1. Term *a*. Carinae sharp, with spines on the three middle ones. This I take to be exemplified by the specimen figured by Brooks (Chall. *Stomatopoda*, Pl. XIV. Fig. 5). There are no true examples of this in the collection.

2. Term *b*. Carinae very swollen, so as to touch one another, without spines. This is the form shown under fig. 15 in my Plate.

One male from Goidu; length 34.

3. Intermediates between these. Four of these show a connection, or traces of a connection, between the median and submedian carinae (cf. figs. 8 and 9).

Numerous examples. Goidu, Goifurfehendu Atoll; Hulule, Male Atoll; Furnadu Velu, Miladumadulu Atoll; Naifaro, Fadiffolu Atoll; all from the reef. Minikoi, "obtained by breaking up a coral mass from the outer reef." Miladumadulu Atoll, 3 *f*. South Male Atoll, 5 *f*.

IX. Var. *mutatus*.

The carinae are very swollen, but the middle three carry spines. 1 ♂ 32, and 1 ♀ 39, Furnadu Velu, Miladumadulu Atoll; 1 ♀ 20, Hulule, Male Atoll; 2 ♂♂ 27, and 21·5, and 1 ♀ 30, Goidu, Goifurfehendu Atoll.

X. Var. *graphurus* Miers.

Closely similar to var. *mutatus*, but distinguished by the presence of sutures on the abdominal terga.

A further distinction between *G. glabrous* and *G. graphurus*, namely the presence of a low *median* carina on the 6th abdominal segment of the latter, has also been insisted on by Miers and Brooks; this distinction is not, however, a real one. In the collection of the Natural History Museum at S. Kensington are several specimens with tumid carinae, with a median carina on the 6th abdominal segment, *but no sutures on the abdominal terga*; these specimens, having been originally labelled *G. graphurus*, have since been re-labelled, and I think rightly, by Dr Hansen as *G. glabrous*. It might be urged that there is no reason to regard the abdominal sutures as a more constant character than the median carina of the 6th abdominal segment; but I have seen examples of undoubted *G. glabrous* in the Natural History Museum (*i.e.* forms with sharply defined carinae) bearing a median carina, or traces of this carina, while Henderson also (*l. c. supra*) remarks "in *G. glaber* this carina is *usually* absent, *or at most but faintly indicated*" (italics mine); whereas I have never found *G. glabrous* showing any signs of the abdominal sutures of *G. graphurus*, though indeed I examined a fairly large number in the Natural History Museum in order to determine whether this character of *G. graphurus* would present transitional stages between itself and the smooth abdomen of *G. glabrous*. I have failed to find any such transitions, and should any other carcinologist consider this single character of sufficient value to separate *G. graphurus*

specifically from *G. glabrous*, this must be a question of interpretation in which we must agree to differ; though, should he agree with me in considering *G. glabrous* as a variety only of *G. chiragra*, I think it would be difficult to consider *G. graphurus* as anything but a variety of the same species, standing a step beyond *G. chiragra* var. *glabrous* in its relation to *G. chiragra* proper.

A further point in which var. *glabrous*, var. *mutatus*, and var. *graphurus* differ from *G. chiragra* is the greater elevation of the carinae, and the presence of two tubercles just beyond the distal end of the median carina, which seem to be correlated; an examination of figures 6—9 and 10—11 will show the stages leading up to this, the carina first becoming raised on a prominence of their own, and the posterior border of that prominence eventually breaking forth into two tubercles in var. *glabrous*. I also give figures of two *glabrous* forms (figs. 8—9) to illustrate some varying appearances of the three median carinae, showing actual connection, or signs of connection, between the submedians and medians: and here I would suggest that, from the point of view of consistency in the nomenclature of the carinae, the carinae on each side of the median carina in *G. chiragra* proper should be called the *lateral* carinae, corresponding to the external, or *lateral*, of the five carinae in var. *glabrous* and var. *graphurus*, reserving the term *submedians* for the intermediate carinae in these latter varieties.

Second heading. I. Var. *incipiens* a, var. nov. Pl. XXIII. fig. 10.

In this the carinae are tumid as in var. *tumidus* and without spines, but the median carina shows the first signs of the 'anchor' in the fact that, at its distal end, the sides are slightly grooved and a small portion separated off; the lateral marginal teeth are also present, but of small size only.

This is represented by a female, length 16·5, in the collection of the Cambridge Museum from Funafuti, Ellice Is., and is one out of some specimens referred to *G. chiragra* by Mr Borradaile. I am permitted to figure this form by the courtesy of Dr S. F. Harmer, F.R.S.

II. Var. *incipiens* b. Pl. XXIII. fig. 11.

The carinae are swollen; the median with a well-developed anchor, but no spine; the lateral marginal teeth well-developed.

This is the form chosen by Dr de Man as the type of the species, and figured by him in *Zool. Jahrb. Syst.* x. Pl. XXXVIII. Fig. 77, and the same as the forms referred to var. A (type) by Mr Borradaile in Willey's *Zool. Results*, Pt. IV. It is not represented in this collection.

III. Var. *segregatus* c. Pl. XXIII. fig. 12.

Forms the same as var. *segregatus* a, described on p. 92, but without a spine at the distal end of the median carina.

Not represented in this collection; but, as stated above, I have seen specimens from the Macclesfield Bank up to 30 mm. in length, and others from Kelantan and Penang in the Malay Peninsula up to 28 mm.

IV. Var. *glabrous* pars.

Carinae swollen, without any spines, or at best but tubercular rudiments of them.

This includes term *b* of this variety, and a certain number of the intermediates which approach very closely to it, the carinae being a little less swollen in varying degrees, and the spines generally absent.

The forms described above may be arranged, as I have said before, in a transitional scheme in such a way that, if we start, for convenience, from the *tumidus*-form, the rest of the forms come to lie along two closely parallel lines (corresponding to the two headings under which I have dealt with them), each of which may take the *tumidus*-form as its starting-point. This arrangement is shown in the following table, and I have affixed letter-symbols to each variety, in addition to the name-symbols, following on the line taken by Mr Borradaile in Willey's *Zoological Results*, Pt. IV. where five varieties are described and lettered from A to E; the first of my varieties, therefore, begins at F, while any varieties referred to by the letters A—E are the same as those correspondingly lettered by Mr Borradaile. The first column in the table forms a very perfect transition-series, but it must not be supposed that the transitions are exactly of the same degree as between form and form; thus, though I have separated var. D into two parts for the purposes of this transition-scheme, I should, had I been dealing with them by themselves, have treated them as one variety; this fact is expressed by giving them the same varietal name. The distinction between var. G and var. D is however definite, they are separated by a greater interval than the two parts of var. D, and this fact is expressed in the difference of varietal name. A similar situation arises in respect of the varieties in the second column in their relation to those of the first column; thus var. H in column 2, can scarcely be separated, on structural grounds, from var. H in column 1, whereas the two forms of var. A in column 2, though their structure requires them to occupy a similar position in column 2 to that which the two forms of var. D occupy in column 1, are still so far distinct from the latter varieties as to require a different varietal name.

This table then I arrange as follows:—

var. F. = *tumidus*

Intermediate between F. and G.	
var. G. = *acutus*	
var. D. = *smithii* a.	var. A. = *incipiens* a.
var. D. = *smithii* b.	var. A. = *incipiens* b.
var. H. = *segregatus* a.	var. H. = *segregatus* c.
var. H. = *segregatus* b.	
var. I. = *glabrous* (term a. and the intermediates near it)	
var. K. = *mutatus*	var. I. = *glabrous* (term b. and the intermediates near it)
var. L. = *graphurus*	

It may not be amiss to consider the facts brought out by an examination of these varieties in their relation to some theoretical considerations brought forward by Mr Borradaile in an earlier part of this work (Vol. I. Pt. II. pp. 193—198 "Marine Crustaceans. I. On Varieties").

1. It will have been noticed that, in cases where there is a sufficient number of any given variety, the individuals representing this variety come, not from one definite locality, but from different localities, a fact which bears out Mr Borradaile's statement, on p. 195, that "*there is no evidence of isolation* such as is presupposed in the evolution of two or more varieties simultaneously from a single species."

2. The transition-scheme which I have given of the *tumidus-glabrous* series has been arranged in two columns, arising out of the fact that two distinct lines of variation are present in the series, one being due to the development of the anchor leading to the formation of the submedian carinae, which is common to both the columns, the other being due to the presence or absence of a spine to the median and submedian carinae, such spines being present in first column (excepting var. *acutus* and *smithii* a.) and absent in the second. Now if the relation of these spines to the carinae be examined, it will be found that, according as the carinae are more tumid, the spines are less prominent; thus, taking extreme instances, it is seen that in var. *smithii* the median carina is almost sharp and has a strong spine, but that in the analogous var. *incipiens* the carina is very tumid and without a spine. Moreover, when, in var. *glabrous*, the carinae become more tumid, so as to produce eventually what I have called above "term *b*," the spines entirely or nearly disappear (var. *mutatus*, however, appears as an exception to this rule), as also do the carinae and spines on the 6th abdominal segment. Thus we find that the shape of the carinae and the development of the spines can only be taken as constituting a single differentiating character, the two apparent variations being, as Mr Borradaile has expressed it, in his footnote 2, to page 197, "coincident." A similar fact has been already brought forward by myself in dealing with some Malaysian Crustacea (*Ann. Mag. Nat. Hist.* (7) VI. 1900), where in dealing with *Actaea pulchella* var. *modesta* (p. 251) I have said, "It is true that three distinctions are noticed, but these three are really only one variation, the curvature of the dactyl and the gape of the fingers being implied by the emargination of the finger-tips." I give this case as another illustration of the point under consideration, and as helping to confirm, together with the present instance of *G. chiragra*, the more theoretical opinions expressed so clearly by Mr Borradaile in his footnote 2, p. 197; with which, I need hardly say, I find myself in entire agreement.

3. In dealing with var. *glabrous*, it has been seen that great difficulty existed in separating the intermediates between the two "terms" into definite groups, and I have above also expressed my reasons for believing that we have in var. *glabrous* a Continuous Variation series; the series being obtained, not from one, but from more than one locality. Now this fact conflicts to a certain extent with some remarks made by Mr Borradaile on pp. 196—7 to the effect that, where "well-characterised non-local varieties" exist, these varieties "are sundered by well-marked gaps"; and the writer adds, "In sorting fifty specimens of two varieties, there would not, in my experience, be more than two or three whose position would be doubtful" (see also footnote 1, p. 197). Now I do not deny the validity of Mr Borradaile's particular facts, which are, of course, cases of Discontinuous Variation, but his remarks seem to imply that, in *all* cases where we find well-characterised, non-local varieties, the variation will be

This includes term *b* of this variety, and a certain number of the intermediates which approach very closely to it, the carinae being a little less swollen in varying degrees, and the spines generally absent.

The forms described above may be arranged, as I have said before, in a transitional scheme in such a way that, if we start, for convenience, from the *tumidus*-form, the rest of the forms come to lie along two closely parallel lines (corresponding to the two headings under which I have dealt with them), each of which may take the *tumidus*-form as its starting-point. This arrangement is shown in the following table, and I have affixed letter-symbols to each variety, in addition to the name-symbols, following on the line taken by Mr Borradaile in Willey's *Zoological Results*, Pt. IV. where five varieties are described and lettered from A to E; the first of my varieties, therefore, begins at F, while any varieties referred to by the letters A—E are the same as those correspondingly lettered by Mr Borradaile. The first column in the table forms a very perfect transition-series, but it must not be supposed that the transitions are exactly of the same degree as between form and form; thus, though I have separated var. D into two parts for the purposes of this transition-scheme, I should, had I been dealing with them by themselves, have treated them as one variety; this fact is expressed by giving them the same varietal name. The distinction between var. G and var. D is however definite, they are separated by a greater interval than the two parts of var. D, and this fact is expressed in the difference of varietal name. A similar situation arises in respect of the varieties in the second column in their relation to those of the first column; thus var. H in column 2, can scarcely be separated, on structural grounds, from var. H in column 1, whereas the two forms of var. A in column 2, though their structure requires them to occupy a similar position in column 2 to that which the two forms of var. D occupy in column 1, are still so far distinct from the latter varieties as to require a different varietal name.

This table then I arrange as follows:—

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var. H. = *segregatus* b.	
var. I. = *glabrous* (term a. and the intermediates near it)	
var. K. = *mutatus*	var. I. = *glabrous* (term b. and the intermediates near it)
var. L. = *graphurus*	

specimen, however, in this collection, namely the largest, the surfaces of the three carinae are nearly smooth; with only a few scattered spinules. The intermediate marginal teeth are much reduced and the lateral marginals obsolete; the carinae of the 6th abdominal segment are considerably swollen, with or without terminal spines.

1 ♂, length 15, 1 ♀, 13, and three very small specimens, Hulule, Male Atoll; and 1 ♀, length 9, Goidu, Goifurfehendu Atoll.

IV. Var. N. = *espinosus* Borradaile.

Approaches nearest to var. *tumidus*, the three carinae being swollen as in that variety, but considerably less so than in var. *spinosus*; it resembles the latter in having the intermediate marginal teeth much reduced and the lateral marginals obsolete. The carinae of the submedian and intermediate teeth are sharply defined: the carinae of the 6th abdominal segment somewhat swollen, only the laterals with spines.

V. Var. O. Pl. XXIII. fig. 13.

Resembles var. *incipiens* a, but has an extra low carina on the median side of the intermediate marginal teeth. East-American.

I have seen, of this variety, one dry specimen in the S. Kensington Museum, and two spirit specimens in the Cambridge Museum; and am permitted to figure one of the latter by the kindness of Dr S. F. Harmer, F.R.S. In this figure it should be noticed that the median carina ends in an 'anchor,' a little more complete, perhaps, than in var. *incipiens* a but less complete than in var. *incipiens* b (compare figs. 10—11 with fig. 13, and these with Dr de Man's Fig. 77). In the brief note in which Dr Hansen describes his *G. oerstedii*, he lays stress only on the point in which his species *differs* from *G. chiragra*, namely the extra carinae on the intermediate marginal teeth, so that he naturally does not state whether the 'anchor' is present or not. As this 'anchor' may or may not be present in the eastern varieties of *G. chiragra*, it no doubt might or might not be present in Hansen's western form. Should Dr Hansen's original specimens be without the 'anchor,' then the name 'var. *oerstedii*' must be applied to the anchorless forms, and these anchored forms must be given a different name; but until this fact is definitely ascertained, I prefer not to name the present form, but to letter it only, for I think it very likely that Dr Hansen's forms will be found to present traces of the 'anchor.' These traces may vary considerably in the degree of their development, just as they do in var. *incipiens*, and in fact, in the second of the two Cambridge specimens, though it is of the same size as the first, the 'anchor' is so imperfect that its presence might be easily overlooked. (The two specimens are of different sexes, but I have seen no evidence of sexual variation in this character in the analogous var. *incipiens* or var. *smithii*.) Moreover, in the specimen from South Kensington, the anchor shows signs of separation from the median carina, though not to the same degree as in var. *segregatus*; the flukes, though quite separated from the median carina, are only imperfectly separated from each other in the middle line. The median carina, in this case, ends in a minute spine. In any case, the presence of the 'anchor' here is interesting as showing the very close affinities of the eastern and western forms, and if the western also varies, like the eastern, in regard to the presence or absence of the anchor, the evidence of relationship is still stronger.

VI. Var. O. ? = *oerstedii* Hansen.

Similar to var. O. but ? without any anchor to the median carina. East-American.

found to be Discontinuous, which I would modify by saying that in *some* (probably *most*) cases of this kind, the variation will be found to be of a nature of the above kind, but that in others it may be Continuous. This fact is of some importance. For, though the number of specimens before us is comparatively small, and though certainty of the presence of Continuous Variations must depend primarily on the examination of a very large series of specimens, yet the evidence before me hardly lets me doubt that, in such a character, for example, as the relative definition of the carinae, we are dealing with a Continuous Variation. Structurally the different degrees of this variation lead insensibly into one another and, statistically, it is not possible to separate the series into two groups, right and left, and say, "Here end the sharply-carinate, here begin the swollen"; the proportion of intermediates is too large for this, their number being greater than that of the two extremes. And, while making due allowance for the deficiency of the evidence owing to the relatively small number of specimens, I cannot but feel that we have here a Continuous Variation either presenting itself along with other Discontinuous Variations or, as in some cases, appearing without them. Now I have drawn attention above to the fairly close correlation between the definition of the carinae and the strength of the spines, the latter variation showing evident signs of discontinuity, so that we arrive finally at the idea of the coincidence, not only of Discontinuous Variations, as suggested by Borradaile, but also of Discontinuous and Continuous (Specific and Normal in Bateson's later phraseology) Variations. As far as the present instance informs us, it appears that, within the species, the Discontinuous is always coincident with the Continuous Variation (*e.g.* var. *smithii* and var. *segregatus* a) while the Continuous may appear without the Discontinuous (*e.g.* var. *acutus*); from the nature of the case this is only what might have been expected.

Third heading. Certain of the varieties of *G. chiragra* do not fall within the transitional scheme given above, nor can I relate them, with any preciseness, to any particular form among those I have described; they are the following:

I. Var. B. of Borradaile = *anancyrus*, Borradaile.

In the tumidity of the carinae and absence of 'anchor' this form resembles var. *tumidus*, but differs from it very notably in the presence of (1) well-developed lateral marginal teeth, and (2) a small tubercular spine on the distal end of the median carina.

II. Var. C. of Borradaile = *acutirostris* de Man.

Carinae not much swollen, without anchor, lateral marginals developed, carinae on submedian teeth converging forwards, angles of rostrum sharp.

I am a little dubious as to the value of the convergence of the carinae on the submedian teeth as a distinctive character: I have never seen this appearance in the numerous examples of the other varieties of *G. chiragra*, which I have examined both here and in the Natural History Museum at S. Kensington, and, as Dr de Man was dealing with a single specimen, it is possible that this very unusual feature represents an individual abnormality. The other characters are, no doubt, distinctive.

III. Var. M. = *spinosus* Bigelow. Pl. XXIII. fig. 14.

The three carinae are exceedingly swollen so as to touch each other along their sides, the carinae of the submedian and intermediate teeth are also swollen, and all the surface of the telson, except the bottom of the grooves, is covered with minute spinules. In one

specimen, however, in this collection, namely the largest, the surfaces of the three carinae are nearly smooth; with only a few scattered spinules. The intermediate marginal teeth are much reduced and the lateral marginals obsolete; the carinae of the 6th abdominal segment are considerably swollen, with or without terminal spines.

1 ♂, length 15, 1 ♀, 13, and three very small specimens, Hulule, Male Atoll; and 1 ♀, length 9, Goidu, Goifurfehendu Atoll.

IV. Var. N. = *espinosus* Borradaile.

Approaches nearest to var. *tumidus*, the three carinae being swollen as in that variety, but considerably less so than in var. *spinosus*; it resembles the latter in having the intermediate marginal teeth much reduced and the lateral marginals obsolete. The carinae of the submedian and intermediate teeth are sharply defined: the carinae of the 6th abdominal segment somewhat swollen, only the laterals with spines.

V. Var. O. Pl. XXIII. fig. 13.

Resembles var. *incipiens* a, but has an extra low carina on the median side of the intermediate marginal teeth. East-American.

I have seen, of this variety, one dry specimen in the S. Kensington Museum, and two spirit specimens in the Cambridge Museum; and am permitted to figure one of the latter by the kindness of Dr S. F. Harmer, F.R.S. In this figure it should be noticed that the median carina ends in an 'anchor,' a little more complete, perhaps, than in var. *incipiens* a but less complete than in var. *incipiens* b (compare figs. 10—11 with fig. 13, and these with Dr de Man's Fig. 77). In the brief note in which Dr Hansen describes his *G. oerstedii*, he lays stress only on the point in which his species *differs* from *G. chiragra*, namely the extra carinae on the intermediate marginal teeth, so that he naturally does not state whether the 'anchor' is present or not. As this 'anchor' may or may not be present in the eastern varieties of *G. chiragra*, it no doubt might or might not be present in Hansen's western form. Should Dr Hansen's original specimens be without the 'anchor,' then the name 'var. *oerstedii*' must be applied to the anchorless forms, and these anchored forms must be given a different name; but until this fact is definitely ascertained, I prefer not to name the present form, but to letter it only, for I think it very likely that Dr Hansen's forms will be found to present traces of the 'anchor.' These traces may vary considerably in the degree of their development, just as they do in var. *incipiens*, and in fact, in the second of the two Cambridge specimens, though it is of the same size as the first, the 'anchor' is so imperfect that its presence might be easily overlooked. (The two specimens are of different sexes, but I have seen no evidence of sexual variation in this character in the analogous var. *incipiens* or var. *smithii*.) Moreover, in the specimen from South Kensington, the anchor shows signs of separation from the median carina, though not to the same degree as in var. *segregatus*; the flukes, though quite separated from the median carina, are only imperfectly separated from each other in the middle line. The median carina, in this case, ends in a minute spine. In any case, the presence of the 'anchor' here is interesting as showing the very close affinities of the eastern and western forms, and if the western also varies, like the eastern, in regard to the presence or absence of the anchor, the evidence of relationship is still stronger.

VI. Var. O. ? = *oerstedii* Hansen.

Similar to var. O. but ? without any anchor to the median carina. East-American.

VII. Var. P. = *festae*. Nobili.

Like var. *oerstedii*, but with spinules on the surface of the telson. West-American.

Of these six (or seven?) varieties, which I have grouped under heading three, the first two, namely var. *anancyrus* and var. *acutirostris*, differ so slightly in structure from *G. chiragra* var. *tumidus* that it would be impossible to consider them as anything but varieties, and as such they are estimated by Borradaile and de Man[1]. The other four present structural differences of somewhat greater magnitude, and have been considered by their authors as distinct species. I differ from these authors on the ground of later knowledge derived from the study of the *tumidus-glabrous* transition-series, which shows (1) that the species as such is highly variable and (2) that even structural differences as great as that between var. *tumidus* and var. *glabrous* are connected by intermediates. In the case of var. *spinosus* and var. *espinosus* we have no evidence of geographical isolation, the former being found both at Mauritius and in the Maldives, the latter being founded on a single specimen only from Rotuma; in the case of var. *oerstedii* and var. *festae* the evidence so far is in favour of such isolation, and we may therefore conclude, for the present, that we are dealing in these cases with distinct sub-species.

KEY TO THE VARIETIES OF *GONODACTYLUS CHIRAGRA*.

Carinae sharp.
- 3 carinae, well-defined.
  - No definite spine on middle carina; no anchor.
    - Rostral angles blunt; carinae on submedian teeth not converging..... *acutus*
    - Rostral angles sharp; carinae on submedian teeth converging ..... *acutirostris*
  - A definite spine on middle carina; anchor present ..... *smithii*
- 5 carinae, of which the submedian are more or less developed.
  - Submedian carinae well-developed with spines ..... *glabrous* (pars)
  - Submedian carinae ill-developed, with or without spines ..... *segregatus*

Carinae blunt, swollen.
- 3 carinae.
  - Telson spinous.
    - An extra carina alongside carina on submedian teeth ..... *festae*
    - No extra carina ..... *spinosus*
  - Telson not spinous.
    - Carinae very swollen, so as almost to touch each other ..... *espinosus*
    - Carinae not very swollen, with definite interspaces.
      - An extra carina alongside carina on submedian teeth ..... *oerstedii*
      - No extra carina.
        - 6 marginal teeth, anchor present ..... *incipiens*
        - 6 marginal teeth, anchor absent ..... *anancyrus*
        - 4 marginal teeth, anchor absent ..... *tumidus*
- 5 carinae.
  - Sutures on the terga of the abdominal segments ..... *graphurus*
  - Sutures absent; spines on the 3 middle carinae ..... *mutatus*
  - Sutures absent; no spines on the carinae ..... *glabrous* (pars)

[1] Var. *acutirostris*, however, differs in a much greater degree than does var. *anancyrus* if the convergence of the carinae on the submedian marginal teeth be taken as a constant character; a character which is so unusual in the species that I have preferred to regard it as a possible abnormality.

2. *Pseudo-squilla ciliata.* Miers.

Miers, *Ann. Mag. Nat. Hist.* (5) v. p. 108, Pl. III. Figs. 7—8 (1880).

♀, Minikoi, "Obtained by breaking up a coral mass from the outer reef," and a young form, Suvadiva Atoll, 30 *f.* (fathoms).

In the young specimen the submedian carinae on the telson, which are small in the adult, are quite absent. In describing the thoracic segments Miers says, "2nd thoracic segment...laterally sub-truncated, 3rd more rounded laterally." I think there must be a slip here on Miers' part, the arrangement in these specimens being just the reverse.

II. LARVAL FORMS.

3. *Alima bidens* Claus.

Claus, *Abh. d. kön. Ges. Wiss. Göttingen*, p. 152, Pl. VIII. Fig. 34 (1872); Brooks, 'Challenger' *Stomatopoda*, p. 90, Pl. IX. Figs. 1—2 (1886).

A single example from Suvadiva Atoll, Maldive Is., 30 *f.*

In this specimen, which is 25·5 mm. long and therefore of the same size as the older of Brooks' two specimens, the three teeth (besides the terminal one) on the dactyl of the raptorial claw are represented by only the merest rudiments under the skin, and there is only one spine on the inner edge of the postero-lateral spine, as opposed to three in Claus', and two in Brooks' specimens; the spines on the postero-lateral angles of the abdominal segments are, however, well-developed.

4. *Alimerichthus pyramidalis* sp. n.

Cp. Claus, *Alimerichthus*, sp. *Abh. d. kön. Ges. Wiss. Göttingen*, p. 147, Pl. VIII. Fig. 30 (1872); and Brooks, 'Challenger' *Stomatopoda*, p. 97 (1886).

Of this species there is one example in the collection. This, which is from the North Male Atoll, is 17 mm. in length and thus corresponds in size with Claus' example, with which, moreover, it corresponds closely in other structural details; there are, however, indications of only 5 (or possibly 6) spines on the dactyl of the raptorial claw, and 5 spines only on the exopodite of the uropod. As points which have not been described before, I may mention that all the abdominal segments bear spines on their postero-lateral angles, while the 6th abdominal segment bears a pair of submedian spines. Also the dorsal spine rises from a pyramidal elevation of the carapace, the angles of which pyramid form carinae, not sharp but rounded, which are continued, one along the mid-dorsum to the rostrum, the other two along the posterior border of the carapace to the postero-lateral spines, the posterior border being bent downwards behind these two carinae.

Claus makes no mention, in his description of this species, of spines on the postero-lateral angles of the abdominal segments, and the point cannot be decided from his figure. Brooks, however, says on p. 98 of his work, "In the true *Alimae* the postero-lateral angles of the abdominal somites end in acute spines, which are not developed in *Alimerichthus*." This I believe to be an error; firstly, because inspection of his figure 3 on Pl. IX. reveals the presence of such spines on at least the 3rd—5th segments; secondly, because the present specimen, which has such spines, agrees so closely with the one dealt with by Claus as to

make it more than probable that, in the absence of definite evidence to the contrary in Claus' work, his specimen was armed with these spines; and thirdly, because similar spines are present in the other example of an *Alimerichthus* described below.

Loc. North Male Atoll, Maldives, 27—35 f.

5. *Alimerichthus unidens* sp. nov.

A single example from South Nilandu Atoll, 19—25 *f.*

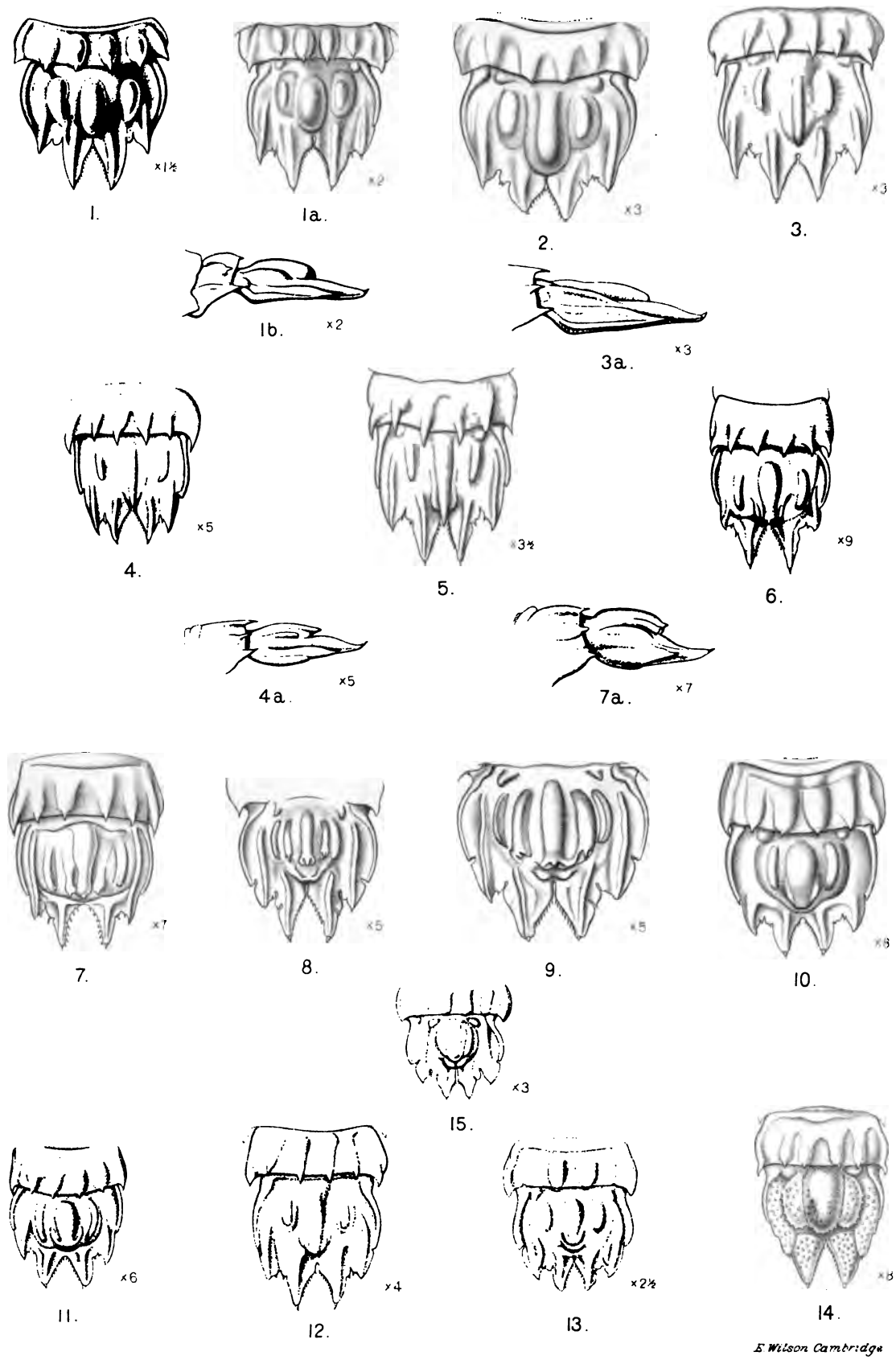
This species agrees in so many points with the preceding that, on a first examination, I was inclined to consider them as identical. The carapace has the same arrangement of primary and secondary spines, and a similar pyramidal support for the dorsal spine; the abdomen has spines on the postero-lateral angles, and submedians on the 6th segment; the uropods and telson are exactly similar. Two conspicuous differences mark the species off very clearly. Firstly, its size; the greatest length of the animal being only 12·5 mm., it is obvious that, were it specifically identical with *Alimer. pyramidalis*, it should represent an earlier stage in the development of that species, a stage in which the uropods should be but little developed and the telson wider in proportion to its length, as is the case even in a specimen 15·5 mm. long figured by Brooks (*l.c.* Pl. IX. Fig. 3); seeing, however, that it is in the same stage, structurally, as the 17 mm. larva described, and as the 16—18 mm. larva of Claus, it is extremely unlikely that we are dealing here with that species; rather we must believe that we have a different larval species in which the structural advances correspond to a smaller advance in size than in *Alimer. pyramidalis.* This view is strengthened by the second difference to be noted, namely, that the dactyl of the raptorial claw is armed with one *fully-developed* spine in addition to the terminal one, and possesses rudiments, proximally to this, of only two others; pointing to its connection with an adult species of *Squilla* in which there are fewer spines on the dactyl than in the adult of *Alimer. pyramidalis.*

6. *Coronideríchthus bituberculatus* Hansen.

Isopoden, Cumaceen, u. Stomatopoden der Plankton Expedition, p. 83 (1895). *Erichthus armatus* Claus (pars), *Abh. d. kön. Ges. Wiss. Göttingen*, XVI. Pl. IV. Figs. 15—15[1] (1872).

One specimen from Suvadiva Atoll, Maldive Is. 44 *f.*, which accords closely with Claus' figures. There is a secondary tooth between the submedians and sublaterals of Hansen, representing his intermediate; in addition, and these are not figured by Claus, are two small spines, one at the base of the sublaterals, the other at the base of the laterals. There are three rudimentary teeth under the skin on the dactyl of the raptorial claw, and two submedian spines on the 6th abdominal segment.

[NOTE. When this paper was written I had not seen the description of two varieties by Dr de Man in a recent paper, "Die von Herrn Prof. Kükenthal...gesam. Dekap. u. Stomatopoden," 1902. Dr de Man's var. *affinis* is coextensive with my var. *segregatus*, his name having priority, but presents certain differences: similarly his var. *confinis* seems to be coextensive with var. *anancyrus*, though again presenting differences. The reader should refer to p. 912 of the above-cited work. Dr de Man agrees with me in considering var. *affinis* as transitional to var. *glabrous*.]



Lanchester – Stomatopoda.

EXPLANATION OF PLATE XXIII.

The telson and 6th abdominal segment of some of the varieties of *Gonodactylus chiragra*.

FIG. 1. Var. *tumidus*, type. 1 *a*. An individual showing traces of the lateral marginal teeth. 1 *b*. Lateral view of the type.

FIG. 2. Form connecting var. *tumidus* with var. *acutus*.

FIG. 3. Var. *acutus*. 3 *a*. Lateral view of the same.

FIG. 4. Var. *smithii* a. 4 *a*. Lateral view of the same.

FIG. 5. Var. *smithii* b.

FIG. 6. Var. *segregatus* a.

FIG. 7. Var. *segregatus* b. 7 *a*. Lateral view of the same.

FIGS. 8, 9. Var. *glabrous*. Forms showing connection, or signs of connection, between median and submedian carinae.

FIG. 10. Var. *incipiens* a.

FIG. 11. Var. *incipiens* b.

FIG. 12. Var. *segregatus* c.

FIG. 13. Var. O = *oerstedii* ?

FIG. 14. Var. *spinosus*.

FIG. 15. Var. *glabrous*, term b.

THE LITHOTHAMNIA OF THE MALDIVES AND LACCADIVES.

By M. Foslie, *in Trondhjem.*

(With Plates XXIV and XXV.)

The Lithothamnia of the tropics have been rather disregarded. Although for a long time known as appearing in a great number of individuals, up to late years only a few species of rather uncertain limits have been distinguished. This applies to the branching as well as crust-like forms. The latter and in part the branching also have often been considered to represent a solitary and supposed cosmopolitan species, *Phymatolithon polymorphum* (*Lithothamnion polymorphum* auct.), while in reality this plant shows a rather restricted geographical distribution, being properly known to occur only in some parts of the North Atlantic and within the southern part of the Arctic Sea. In regard to species also the Lithothamnia have now been shown to be richly represented in the tropics, as of late years rather numerous species have been described. Little, however, is as yet known with regard to their geographical and vertical distributions. Therefore, every contribution may help to extend our knowledge of these plants, which appear to be significant and interesting in several respects.

Till now not a single species with certainty has been recorded from the great area between the Red Sea and the East Indies. Mr Stanley Gardiner, however, collected a number of Lithothamnia during his expedition to the Maldives and Laccadives in 1899—1900. He has done me the favour of submitting this collection to my research. It is interesting, especially as regards the geographical distribution of several species, and at the same time tends to show what forms chiefly act together with corals as reef-builders.

The calcareous algae in question, in the northern temperate zone as well as in the Arctic Sea, occur rather independently and, as a rule, form greater or smaller banks in the sublittoral zone down to a depth of about 20 fathoms[1]. In the tropics these algae partly seem to be confined to coral-reefs, and partly form independent banks, which mainly consist of calcareous algae freely, or apparently freely, developed on the bottom. The growth of the species under different conditions, however, is still but little observed, as well as to what extent banks, or masses, of these algae occurring on reefs consist of one or more species. I may mention that banks in the tropics seem not unfrequently to be composed of a single species, as is very often the case in the temperate zone. Thus the Challenger expedition

[1] F. R. Kjellman, "The Algae of the Arctic Sea." Stockholm, 1883. M. Foslie, "The Norwegian Forms of Lithothamnion." Trondhjem, 1895.

met with a bank off Tahiti, which had probably been formed by a single species, *Lithothamnion Dickiei*[1]. In *Suppl. Alg. Tahiti*[2] the following note is added:—"A calcareous alga in rounded masses forming the bottom in 10 fathoms off Great Island (Santa Cruz Major), Zambonga. The dredge came up filled with these masses." The Dutch Siboga expedition has pointed out several banks in the Malayan Archipelago, which apparently consist of only one species or have one especially predominating[3]. A peculiar occurrence of large quantities of a Lithothamnion has been mentioned by Madame A. Weber—van Bosse from the above expedition off Haingsisi on the Samau Island near Timor. Here *Lithothamnion erubescens* f. *haingsisiana* in the littoral zone forms a bank which becomes dry at low tide. It is indeed well-known that Lithothamnia occur between tide marks, and that certain forms even chiefly are to be found there; for instance some forms live in shady localities or in rock-pools, which are filled with water at the ebb, yet none grow in large quantities except in the lowest part of the zone and are then for a short time only more or less dry. In such parts as are completely dry for several hours, at any rate in the northern temperate zone and within the Arctic circle, are generally found only crust-like species. Branching forms are seldom met with even in the lower part of the littoral zone, and almost only such as at the same time form a rather strong crust. But in the above places *Lithothamnion erubescens* occurs—forming rather large nodules, which are richly, but densely branched—in such masses that the plant makes its mark in the vegetation, or forms a real bank (*Vide l.c.* Pl. XVIII—XIX). Nothing like this appears to have been met with before.

It seems as if some Lithothamnia do not thrive in connection with certain corals or especially certain Polyzoa, but on the other hand, as remarked above, other species appear to be rather confined to coral-reefs. These algae in general are apparently not dependent on physical or chemical conditions, apart from requiring, like other algae, at least a fairly hard bottom, and besides as a rule a partly exposed habitat over which the tides are running more or less rapidly. But some species, which frequently stick to stones or shells of mollusks, show a tendency in some degree to modify their structure when attached to certain corals or coarse Polyzoa, while the same species growing on other corals or Polyzoa do not differ from their typical development. This is due to the hypothallic or basal layer of the plant and of course owes its origin in the main only to the size of the cells and the mutual proportions between the hypothallic and perithallic layers of tissue. Moreover, such species which form real and independent banks at the bottom seldom or never appear to occur in coral-reef areas. Other species on the contrary seem to prefer corals as substrata or places where they abound. There are species known only from coral-reefs, or occurring on them in much larger numbers and more vigorously developed than in other places, but there are also species appearing equally distributed both on such reefs and in other places suitable for their development. It seems even to be a rule that species which principally appear on coral-reefs frequently are to be found in great masses, though properly speaking scarcely forming definite banks. These relations are as yet but little observed. It appears, however, to be worth a closer investigation whether the points suggested above depend on accidental circumstances or are of a more crucial significance.

[1] M. Foslie, "New or critical calcareous Algae." Trondhjem, 1900.

[2] Dickie, "Notes on algae collected by H. N. Moseley of H.M.S. 'Challenger,' chiefly obtained in Torres Straits, coasts of Japan, and Juan Fernandez." *Linn. Soc. Journ. Bot.*, Vol. xv. p. 452: 8. "Algae collected on the Reefs of Tahiti." 9. "Supplement to preceding collection."

[3] A. Weber—van Bosse, "Études sur les algues de l'Archipel Malaisien." *Annales du Jardin Botanique de Buitenzorg*, Ser. 2, Vol. II. p. 126. Leide, 1901.

Among the calcareous algae in question which only, or almost only, occur on coral-reefs and there play a prominent part as reef-builders, it seems as if the coarse *Lithophyllum craspedium* may be placed in the front rank. Thus this species is apparently the predominant alga in certain atolls of the Maldives (Pl. XXV. fig. 1). The same species also abounds at Funafuti, and at Onoatoa, Gilbert Islands, is a very abundant type. According to a label, "this Nullipore, Finckh says, is actually the reef-former at Onoatoa. He saw no live coral there, but everywhere on the lagoon and ocean-face immense masses of this particular Nullipore." Next to the last named species, *Goniolithon frutescens* appears to be abundant in the Maldives, and is there especially numerous on the sand-flat of Hulule, Male Atoll. This rather finely branching species also occurs at Minikoi Atoll in the Laccadives. Further it is common at Funafuti, where it was first met with, and the collector remarks that the species is very abundant off the leeward (W.) islets, but is also found in great numbers in other parts; he considers it to be a rather important reef-builder. A form of this species, represented by dead and fragmentary, apparently rather young specimens, also from Funafuti, has been indicated as an important rock-former; the specimens comprise especially the crustlike parts of the plants with short branches, but in contradistinction to other specimens are of a hard consistency. They in part remind one of calcareous sediment, and are anastomosed with fixed corals or fragments of corals. In addition, the crustlike *Lithophyllum oncodes* appears to act as a kind of cement, and is apparently abundant in the Maldives as well as at Funafuti and other places both in the Indian and Pacific Oceans. There are still a number of other species, which in greater or less degree contribute to the formation of reefs, and sometimes even form layers almost alternating with corals, Polyzoa, Foraminifera, etc. Their occurrence and significance are, however, too little known to me to be specially mentioned here.

It has been considered by some recent authors that algae having an incrustation of carbonate of lime occur much more plentifully in the warmer than in the temperate oceans; or, in other words, a very slight amount of carbonate of lime is supposed to be developed in the cold waters of the polar regions. According to our present knowledge of the distribution of the Lithothamnia in different zones, this view is not correct. On the contrary, numerous large banks of these algae are to be found in the Arctic as well as in the temperate zone, though the number of species is less in the former seas. Thus on the coast of Spitzbergen and Nowaya Zemlya *Lithothamnion glaciale* "covers the bottom in deep layers for several miles, and altogether determines the general aspect of the vegetation, wherever it occurs. In the formation of future strata of the earth's crust in this region it must become of essential importance[1]." It is also known that *Lithothamnion Ungeri* forms banks on the coast of Iceland, and also on the coast of Greenland. Indeed, these algae are common and plentiful, partly even occurring in masses[2]. North of the polar circle on the coast of Norway banks have been met with, which cover the bottom for several miles, and plants appear in immense masses frequently representing only one species. Farther to the south, for instance in the Trondhjem Fjord, rather large banks are to be found which may be composed of a solitary small species such as *Lithothamnion norvegicum*, or other and extensive banks of larger species which form deep layers built up in vertical direction, so that they in part may be almost laid dry at lowest springs. In the same locality subhemispherical specimens have been found, which vary up to half a metre in diameter, weighing nearly 6 kilogrammes in a dried state. Similar specimens are also found on the south-west

[1] F. R. Kjellman, "The Algae of the Arctic Sea." Stockholm, 1883, p. 96.

[2] Kolderup Rosenvinge, *Grönlands Havalger. Kjobenhavn*, 1893, p. 772.

coast of Norway. The banks in these positions are built up entirely of the algae in question, and as a rule each bank comprises only one species, but at the same time it serves as a shelter for a very great number of various animals, though not corals. In such banks is often to be seen an interesting struggle for existence between plants and animals. Further it may be remarked, that in several places along the Norwegian coast rather large quantities of dead Lithothamnia have been brought up by excavators in harbours, where living specimens are no more to be found. On the west coast of Ireland I have also seen great masses of partly dead, partly living, specimens. On the whole, smaller or larger banks appear almost everywhere at least in northern waters, in places where the nature of the bottom allows their existence and the tides are running rapidly.

In regard to the habitat of the Lithothamnia in the Maldives, Mr Stanley Gardiner kindly communicated to me some observations on the collection, of which I may quote the following. The names within parentheses are added by me as the supposed species in question.

"The finely branching species or specimens are all from the sand-flat (*Goniolithon frutescens*). Massive (not branching) forms are practically invariably from the outer, i.e. seaward face of the reef near the breakers. Specimens roughly resembling (*Lithothamnion fruticulosum* f. *crassiuscula* and *Lithophyllum Kaiserii*?) are almost invariably dredged either to seaward of the reef or in passages generally down to about 25 fathoms. Rounded nodules like marbles or eggs (*Lithophyllum Reinboldi*?) are invariably from deep passages into the lagoons of atolls or interiors of banks. They lie there together with similarly shaped masses of *Polytrema* and Polyzoa (each usually with a nucleus of dead coral). Presumably all these are rolled over and over with the currents.

"In the lagoons of Suvadiva, Addu and other closed atolls Lithothamnia were never dredged. Perhaps this was partially owing to the sandy or muddy bottom preventing their growth, but even close round shoals, where the bottom was covered with coral fragments, Lithothamnia were never found. In similar situations to the last in the open banks of Miladumadulu and N. Mahlos I have found small growths a square centimetre or so, but never obtained a separate large plant."

"In reference to the reefs, branching growths (*Goniolithon frutescens*) may be found more or less imbedded in the sand of the sand-flat in any situation where they are never uncovered and the water circulates freely. Thus to the E. of Hulule such growths were found, but not on the west or lagoon side. On the reef to the E. (seaward reef) the Lithothamnia presented their usual abundance, most plants being encrusting with smooth surface (*Lithophyllum oncodes* and *Goniolithon Fosliei*), some however coarsely mamillated (*Lithophyllum craspedium*). At the extreme edge under the breakers massive or incrusting growths covered the greater part of the rock on many reefs, and on the reef-flats behind a few plants were growing in hollows. On the W. reef (lagoon reef) of Hulule island no Lithothamnia were ever found except at the extreme edge. Here such growths as existed were very small and crowded out by corals. Several series of dredgings were taken off this reef in 10, 15, 20, 25 and 28 fathoms. The only Lithothamnia obtained were two small nodules between 25 and 30 fathoms almost off the end of the passage."

Genus **Archaeolithothamnion** (Rothpl.) Fosl.[1]

1. *A. Schmidtii* Fosl.

Corall. in Schmidt, *Fl. Koh Chang*, II. p. 16.

f. *dissita* Fosl. mscr. (Plate XXIV. fig. 1).

Branches rather scattered and up to 3 mm. thick, increasing in thickness upwards.

Only two specimens were till now known of the typical form of this species, and these so exactly resembled each other, that it is uncertain whether the species shows any tendency to variation. Notwithstanding this, I refer the above form to *A. Schmidtii*, although it rather differs in habit from the type of the latter. Thus even in an advanced stage the branches are not so crowded as in the typical form, but the crust itself is of about the same thickness. They frequently issue at intervals of 3—5 mm., nearly always increasing in thickness upwards, or occasionally with almost spherically thickened ends, and up to about 8 mm. long. In addition they are most often thicker than the average in the type, but on the other hand less knotty. In regard to structure and sporangia the plant in the main agrees with the typical form. There seems, therefore, to be reason, at least at present, not to consider f. *dissita* more than a form of *A. Schmidtii*.

The present form of the species appears to grow in somewhat sheltered places. It is, however, according to the label only known with certainty from the lagoon of Addu atoll (25 fathoms). About this atoll Mr Stanley Gardiner remarks: "Its reef is perfect except for two small passages to the north and two larger ones to the south. The lagoon has a maximum of depth of 32 fathoms; it is fairly open in the centre, but against the encircling reefs has a perfect maze of coral heads, arising from 7 to 10 fathoms." The plant was sterile when dredged in the middle of April, being however sparingly provided with overgrown cavities of sporangia.

Locality. The Maldives. Only one specimen with certainty known from the most southern part of the Maldive group, viz. Addu atoll. Another and a younger one is perhaps from Hulule, Male atoll, though possibly from some other atoll.

Genus **Lithothamnion** Phil. (Fosl. emend.).

2. *L. fruticulosum* (Kütz.) Fosl.

List of Lith. p. 6 (non Norw. Lith.); *Spongites fruticulosa* Kütz. *Polyp. Calcif.* p. 33 et *Tab. Phyc.* 19, t. 99. Syn. *L. fasciculatum β. fruticulosum* Hauck, *Meeresalg.* p. 274.

f. *clavulata* Fosl.

Corall. in Schmidt, *Fl. Koh Chang*, p. 17.

f. *crassiuscula* Fosl. (Plate XXIV. fig. 2).

Corall. in Schmidt, *Fl. Koh Chang*, p. 17.

Three small and rather delicate specimens of f. *clavulata* from two localities coincide with the specimens known from the Gulf of Siam. They also fully agree in habit and

[1] With regard to the limit of the genera I refer to "Revised Systematical Survey of the Melobesieae." Trondhjem, 1900.

structure with somewhat stunted growths from the Mediterranean and the Adriatic. The only difference appears to be, that the conceptacles of cystocarps are more acute than generally seen in specimens from the last-named regions. Therefore, there seems to be no reason to consider the alga from the Indian Ocean, hitherto only known from the Gulf of Siam and the Maldives, as a form so differing from the Mediterranean and Adriatic f. *clavulata*, that it ought to be specially denominated.

As remarked in a pamphlet in press[1] there is a considerable difference in habit between a delicate f. *clavulata* and a coarse f. *crassiuscula*, but I have been unable to draw any true limit between them. They are both pictured in the said pamphlet together with a still more delicate and rather curious form, which I have named f. *soluta*. A coarse specimen of f. *crassiuscula* is also to be found in the collection from the Maldives (Plate XXIV. fig. 2). It seems as if this form has a tendency to get a little coarser in the tropics than is generally the case in the Mediterranean or the Adriatic, as in the latter regions the greatest number of specimens show slightly thinner branches, although not seldom fully agreeing even in this respect. On the other hand the specimen from the Maldives fully coincides with the same form of the species known from the south coast of Australia, where it seems to be rather abundant. This form probably occurs also in other parts of the Indian as well as Pacific Ocean.

Besides the specimen of f. *crassiuscula* four other specimens were found in the present collection. These represent a form which is closely connected with f. *crassiuscula*, but differing in some respects (Plate XXIV. fig. 3). The specimen here pictured reminds one in habit of an old *Goniolithon Brassica-florida*, but, as mentioned in the above quoted pamphlet, in the Adriatic as well as in the Mediterranean these two species sometimes rather approach each other in that respect, though otherwise being quite different. These four Maldive specimens form nodules up to about 6 cm. in diameter, which look as if they had been freely developed at the bottom. They surround. at least in part, pieces of corals. Their consistency is more compact than in typical f. *crassiuscula*, the surface even a little shining, but, above all, their conceptacles of sporangia are somewhat smaller. The latter sometimes are about 600 μ in diameter seen from above, but in most cases only 400—500 μ. They are now and then slightly depressed in the central part, especially towards maturity, and their muciferous canals are somewhat crowded in the roof, as also occasionally occurs in typical specimens of the form.

In structure this Maldive form coincides in the main with typical *L. fruticulosum*. A section shows that the plant has been much attacked by lower animals, and numerous new formations have been built up over each other, in part almost alternating especially with Polyzoa. A consequence of this often seems to be, that the hypothallic layer gets more vigorously developed, or the cells larger and, especially, more elongated than would otherwise be the case. I have formerly shown that, for instance in *Lithothamnion Philippii*, the corresponding cells under similar conditions sometimes become even much larger than under a normal development. This seems especially to be the case when the plant sticks to certain Polyzoa, chiefly coarse and large-celled ones, while on the other hand certain corals seem to give rise to a rather feeble development of the basal layer of the plant. In several of the new formations in the specimens the hypothallic layer is vigorously developed, more or less coaxillate, and often composed of larger cells than generally observed in the species. The

[1] "Die Lithothamnien des Adriatischen Meeres und Marokkos." *Wissensch. Meeresuntersuchungen, Abt. Helgoland.*

cells of the perithallic layer vary greatly in size, as is often the case in calcareous algae burdened with animals. They coincide, however, in the main with the species in question.

Therefore, also these four specimens in my opinion must be referred to *L. fruticulosum*, and are so closely connected with f. *crassiuscula* that in fact they probably only represent an outer limit of this form. A solitary specimen from the most southern part of the Maldive group, Addu atoll, is perhaps referable to the same species. It seems to have been dead when picked up from a depth of about 40 fathoms, but as sterile and not typical it cannot be determined with certainty.

At the Maldives the species apparently occurs in the sublittoral zone and under much the same conditions as in most other places. It is not known with certainty from what depth this plant was dredged in Male atoll, but in S. Nilandu, "an atoll somewhat similar to Male," f. *clavulata* was obtained at 19 and 35 fathoms, thus rather deeper than for instance in the Gulf of Siam, where it was brought up from 9 fathoms. Indeed f. *clavulata* appears frequently to descend deeper than f. *crassiuscula*. Both forms are provided with reproductive organs in January, especially sporangia, while carpospores are scarce.

Locality. The Maldives: Hulule, Male atoll (f. *crassiuscula* and a small specimen of f. *clavulata*); S. Nilandu (f. *clavulata*); and Addu atoll (uncertain).

Genus **Lithophyllum** Phil. (Fosl. emend.).

3. *L. Reinboldi* A. Web. et Fosl. (Plate XXIV. fig. 4) in *Vidensk. Selsk. Skr.* 1901, no. 1.

In the collection there was a well-developed typical specimen of this species from the Laccadives, attached to an oyster-like shell, and another and quite young one, sticking to a piece of coral. A single specimen from the Maldives (Plate XXIV. fig. 4) bears a few young branches of *Goniolithon frutescens*, which shows that both species probably appear gregariously in the same habitat.

It seems as if this species partly grows in the lower part of the littoral zone, partly in the upper part of the sublittoral zone, but apparently not descending to any considerable depth. At the Laccadives the plant is furnished with sporangia towards the end of July, and at the Maldives in the latter half of April.

This species appears to be widely dispersed in the Indian Ocean. It has been known for a long time from Samoa and Zanzibar, but was not described until collected by Madame A. Weber—van Bosse on Moearas-reef, east coast of Borneo, and at Banda during the Siboga expedition. It is also known from the Tami islands, New Guinea (*L. cerebelloides* Heydr.), and the Hawaiian islands in the Pacific Ocean.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

4. *L. craspedium* Fosl.

New or crit. calc. Alg. p. 26.

f. *compressa* Fosl. (Plate XXV. fig. 1).

Calc. Alg. Funafuti, p. 7.

f. *abbreviata* Fosl. (Plate XXV. fig. 2).

Calc. Alg. Funafuti, p. 7.

sometimes approaches *Lithophyllum congestum* in habit, or even reminds one of *L. platyphyllum*, while as remarked above the species in fact is most closely related to *L. racemus* and *L. Okamurai*.

This species seems to occur in the sublittoral zone, but it is unknown to what depth it descends. It is most frequently attached to corals, from which, however, it seems sometimes to loosen itself, or is freely developed at the bottom. The plant is sparingly provided with reproductive organs in January.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll, quite young and not certain.

6. *L. oncodes* Heydr.

Lithothamnion oncodes Heydr. in *Bibl. Bot.* 41, p. 6; and *Ber. Deutsch. Bot. Ges.* 1897, p. 410.

The species forms more or less thick and rather smooth crusts on rocks or corals. At the Maldives as well as the Laccadives it appears partly in its typical, partly in a somewhat varying form. The latter shows a rather uneven surface, which in the main depends on the shape of the substratum, and in addition slightly differs in structure. On a cross section the cells are here and there larger than is generally found, more regular, and with their longest diameter in a vertical direction. These differences seem to me not to be of such importance that they justify one in supposing it a separate species or form.

The plant always appears to occur in the lower part of the littoral and uppermost part of the sublittoral zone, scarcely descending deeper. It often grows in company with other species, as *Lithophyllum craspedium* and *Goniolithon frutescens*, and seems in some places to be a rather important reef-builder. Specimens collected in the Maldives in January and in the Laccadives towards the end of July are partly furnished with reproductive organs.

Locality: the Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

Genus **Goniolithon** Fosl.

7. *G. frutescens* Fosl.

Calc. Alg. Funafuti, p. 9.

f. *typica* (Plate XXV. fig. 4).

f. *congesta* Fosl. mscr. (Plate XXV. fig. 5).

Branches densely crowded and fastigiate.

In the typical form, as well as in f. *flabelliformis*, the branches are rather irregular in height and most often not densely crowded, reminding one in habit of the similar forms of *Lithophyllum moluccense*. In f. *congesta* on the other hand the plant forms hemispheric or roundish balls up to 6—7 cm. in diameter, with densely crowded and on the whole strongly fastigiate branches (Plate XXV. fig. 5). Besides, the branches frequently are thinner than in the other forms, seldom more than 2 mm. thick. This form is very characteristic in its typical shape, showing however numerous transitions to f. *typica*, although even in a young state the branches are a little thinner, with proportionally shorter axes than in the latter. Plate XXV. fig. 6 shows a young specimen of an intermediate form, which however comes nearest to f. *congesta*. Typical specimens of f. *flabelliformis* are not to be found in the

present collection, but on the other hand rather numerous and well-developed specimens of f. *typica*.

This species appears to be widely dispersed in the Indian, as well as a part of the Pacific Ocean. Together with *Lithophyllum craspedium* and *L. oncodes* it seems to be the most abundant calcareous alga of the Maldives, and apparently is also rather common in the Laccadives. The plant probably occurs gregariously, especially in the lowest part of the littoral zone and upper part of the sublittoral, and is partly attached to corals or rocks, partly either freely developed at the bottom or imbedded in the sand of the sand-flats. It also seems often to loosen itself from the substratum and to continue its growth in the free state. The specimens are provided with reproductive organs in January, although rather sparingly.

Locality. The Maldives: Hulule, Male atoll, and Suvadiva atoll; and the Laccadives: Minikoi atoll.

8. *G. Brassica-florida* (Harv.) Fosl.

List of Lith. p. 9; *Melobesia Brassica-florida, Harv. Ner. Austr.*, p. 111.

f. *laccadivica* Fosl. mscr. (Plate XXV. fig. 7).

Thallus forming crusts on corals 0·5—1·5 mm. thick, with simple or sparingly divided short branches, 2—2·5 mm. thick. Conceptacles of sporangia conical, 800—900 μ in diameter when seen from above.

The present plant surrounds a branch of a coral, the latter towards 1 cm. thick, and forms a crust 0·5—1·5 mm. thick. From this crust issue crowded in part somewhat anastomosing branches which are simple or sparingly divided, frequently 3—7 mm. long and 2—2·5 mm. thick, with rounded ends. The branches are now and then knotty.

The hypothallic layer is well-developed, coaxillate, and the cells frequently 15—25 or up to 30 μ long and 9—12 μ broad. The perithallic layer forms more or less distinctly stratified layers of tissue, partly with rounded cells 9—12 μ in diameter, partly and most frequently with vertically elongated, 12—18 μ long and 9—12 μ or occasionally 15 μ broad. Here and there appear rows of larger cells. Heterocysts are not numerous.

The conceptacles of sporangia are to be found somewhat scattered in the branches. They are conical, a little contracted in the middle part, but their more or less elongated upper part falls away at maturity. They are 800—900 μ in diameter, seen from above, and the sporangia are four-parted, 120—160 μ long and 45—55 μ broad.

I have been uncertain whether this plant ought to be considered a form of the above species, or should be regarded as a separate one. Only two fragmentary pieces are known, and these appear to be rather young. The plant is, however, in several respects closely allied with *G. Brassica-florida*, and, therefore, I place it as a form of the latter until older specimens may be known. It somewhat differs from typical specimens of the species both in habit and structure, but on the other hand it must be borne in mind that *G. Brassica-florida* is a rather varying plant both in habit and even in structure, in the latter respect owing to the fact that it is frequently attacked by lower animals, especially worms, which nearly always show a disturbing influence on the normal development of the layers of tissue.

It is unknown under what conditions f. *laccadivica* appears, probably however in the lower part of the littoral zone, or in shallow water in rather sheltered habitats. It bears ripe sporangia towards the end of July.

Locality. The Maldives: Hulule, Male Atoll, a quite young and sterile specimen appears to belong to the form in question; and the Laccadives: Minikoi Atoll.

9. *G. Fosliei* (Heydr.) Fosl. (Plate XXV. fig. 3).

In *Vidensk. Selsk. Skr.* 1901, No. 2, p. 8.

Lithothamnion Fosliei Heydr. in *Ber. Deutsch. Bot. Ges.* 1897, p. 58; ex parte sec. spec.; *Lithophyllum Fosliei* Heydr. *l.c.* p. 410.

As remarked by me (*l.c.*) this species in part included an *Archaeolithothamnion.* According to remarks of its author it properly is a *Lithophyllum,* but the latter genus includes in his opinion also *Goniolithon.* Therefore, I here refer the species to this genus, in part according to an authentic specimen that I possess, in addition to the specimens in this collection. It appears, however, to me to be a question whether the species does not represent a new subgenus of *Goniolithon,* as the carpospores in some respects differ from the type of the latter, but the significance and value of this difference is not yet fully known.

The species in several respects comes near to *Goniolithon Notarisii,* especially in regard to the sporangia. The last-named organs have till now been unknown. In one of the specimens from the Laccadives I met with conceptacles of sporangia, and in another with conceptacles of cystocarps. The former are 450—650 μ in diameter seen from above, thus rather smaller but of the same shape as the conceptacles of cystocarps, which are 800—1100 μ in diameter. The sporangia are four-parted, 70—80 μ long and 30—40 μ broad.

As far as hitherto known the species frequently sticks to corals in the uppermost part of the sublittoral zone, and perhaps also in the littoral zone. It appears to grow in company with other species, sometimes even anastomosing with these, such as *Lithophyllum craspedium* and *L. oncodes.* Plate XXV. fig. 3 shows a rather young specimen attached to a coral. In the Laccadives the plant is provided with reproductive organs towards the end of July.

Locality. The Maldives: Hulule, Male atoll; and the Laccadives: Minikoi atoll.

EXPLANATION OF PLATES XXIV—XXV.

All the figures from photographs in natural size.

Plate XXIV.

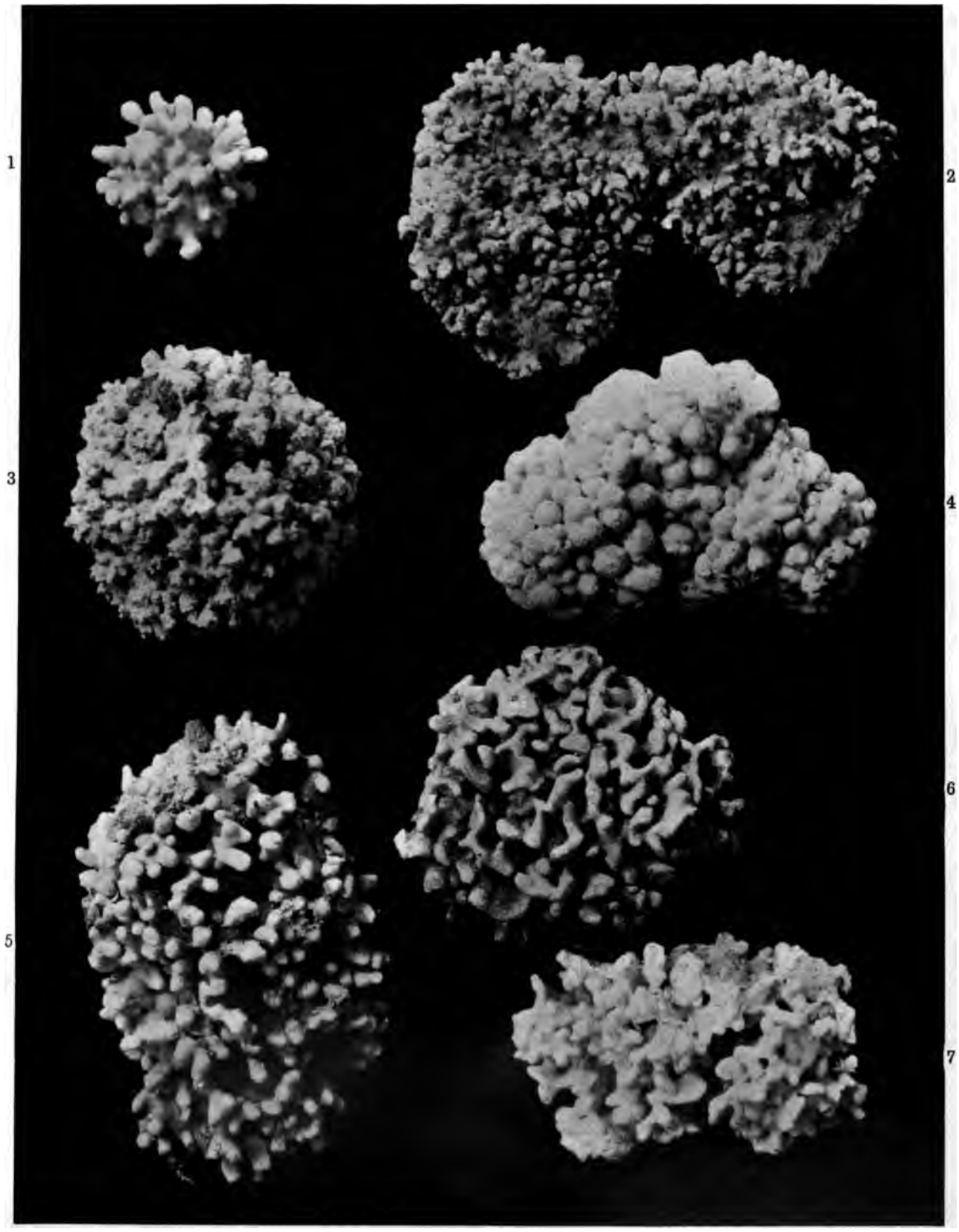
Fig. 1. *Archaeolithothamnion Schmidtii* f. *dissita* Fosl. An apparently young specimen, almost surrounding a coral.

Fig. 2. *Lithothamnion fruticulosum* (Kütz.) Fosl. f. *crassiuscula* Fosl. A fully developed specimen, attached to a coral.

Fig. 3. *Lithothamnion fruticulosum* (Kütz.) Fosl. forma. An almost spherical specimen of a rather hard consistency, with rather numerous partly overgrown Polyzoa and other animals.

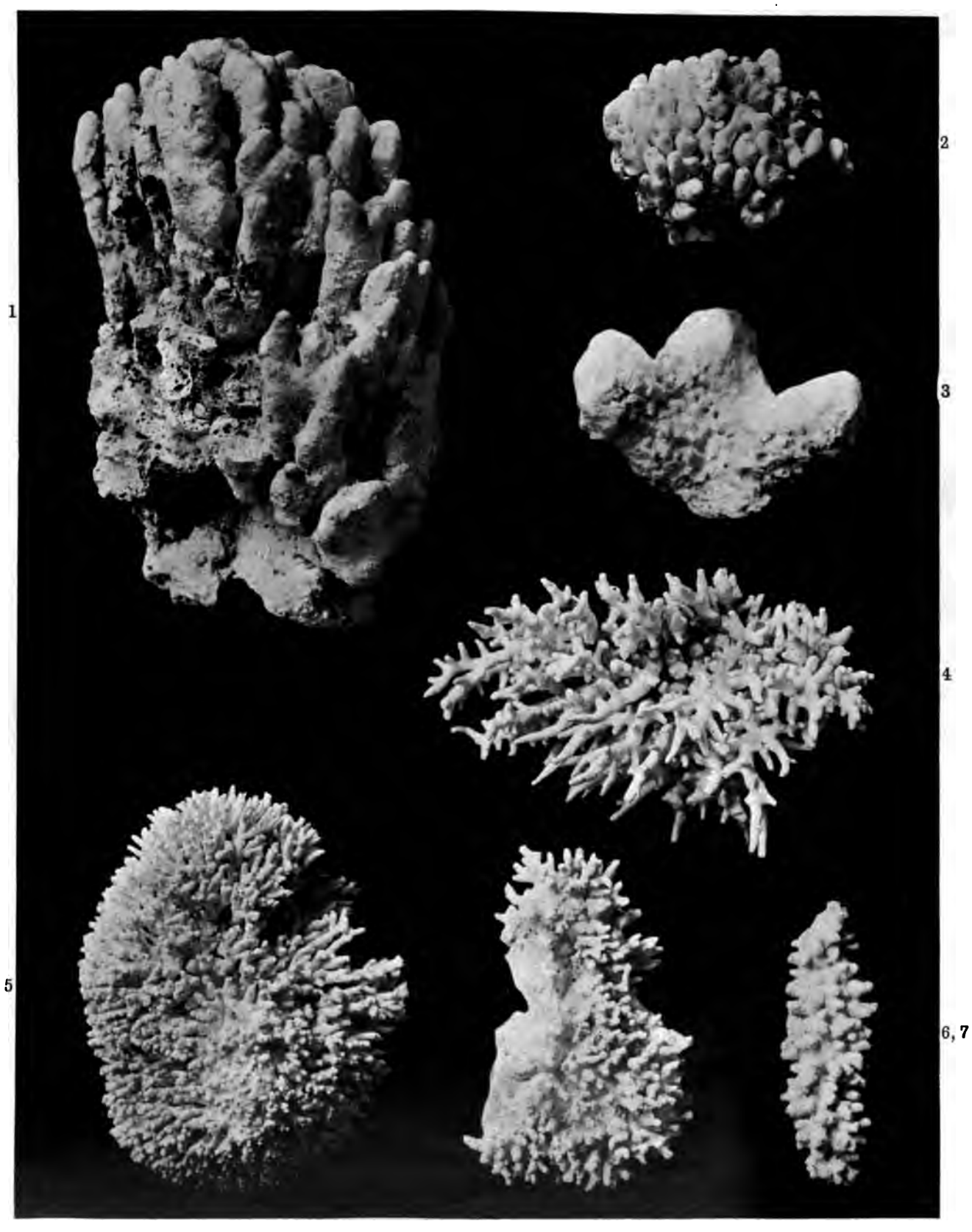
Fig. 4. *Lithophyllum Reinboldi* A. Web. et Fosl. A rather young but typically developed specimen, attached to a coral.

Fig. 5. *Lithophyllum Kaiserii* Heydr. A coarse form of the species.



FOSLIE——LITHOTHAMNIA.

To face p. 470.



FOSLIE——LITHOTHAMNIA.

To face p. 471.

FIG. 6. *Lithophyllum Kaiserii* Heydr. A coarse specimen of a form most nearly related to f. *subplicata* Fosl.

FIG. 7. *Lithophyllum Kaiserii* Heydr. An almost typically developed specimen of the species.

PLATE XXV.

FIG. 1. *Lithophyllum craspedium* f. *compressa* Fosl. A rather typical specimen of the form.

FIG. 2. *Lithophyllum craspedium* f. *abbreviata* Fosl. A fully developed specimen, showing the transition to f. *subtilis* Fosl.

FIG. 3. *Goniolithon Fosliei* (Heydr.) Fosl. A rather young specimen of the species, attached to a coral.

FIG. 4. *Goniolithon frutescens* Fosl. f. *typica*. An apparently freely developed specimen of the plant.

FIG. 5. *Goniolithon frutescens* f. *congesta* Fosl. A roundish or almost subhemispheric specimen with a coral nucleus.

FIG. 6. *Goniolithon frutescens* f. *congesta* Fosl. A young specimen sticking to a coral, giving transition to f. *typica*.

FIG. 7. *Goniolithon Brassica-florida* (Harv.) Fosl. f. *laccadivica* Fosl. A rather young specimen, surrounding a branch of a coral.

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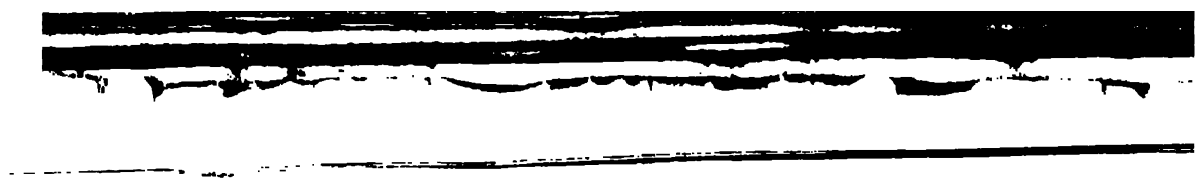

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